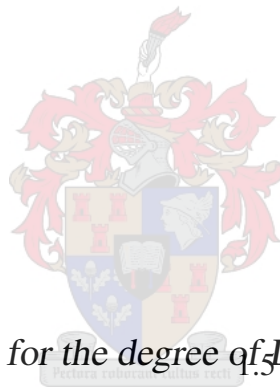


# **Essays on Macroprudential Policy and Financial Stability: The Case of South Africa**

by

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*Dissertation presented for the degree of Doctor of Philosophy in  
Economics in the Faculty of Economic and Management  
Sciences at Stellenbosch University*

Supervisor: Prof. Guangling Liu

March 2020

# Declaration

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# Abstract

## **Essays on Macroprudential Policy and Financial Stability: The Case of South Africa**

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This thesis contributes to the literature on macroprudential policies for the South African economy. The main goal of the thesis is to enhance our understanding on how macroprudential policies work, their effectiveness, transmission channels and their interaction with the monetary policy. The thesis consists of three main chapters. Chapter 2 develops a real business cycle dynamic stochastic general equilibrium (DSGE) model that features a stylised banking sector, a housing market and a role of a macroprudential policy, and examines the extent to which the Basel III bank capital regulation attenuates fluctuations in housing and credit markets and fosters financial and macroeconomic stability. Secondly, we compare the effectiveness of four different Basel III countercyclical capital requirement (CcCR) rules in terms of enhancing financial and macroeconomic stability. The results show that the rule-based Basel III CcCR effectively attenuates fluctuations in credit and housing markets and mitigates the procyclicality of the Basel II capital regulation. The impact of a permanent increase in capital requirement ratio (a 2.5% conservation capital buffer) is marginal. The comparative assessment of the four Basel III CcCR rules suggests that the most effective policy rule is the one in which the authority adjusts bank capital requirement ratio to credit and output gaps.

Chapter 3 investigates the implications of the countercyclical loan-to-value (CcLTV) regulation in a setting where household and non-financial corporate borrowers co-exist. To do this, we consider two policy regimes - one generic and one sector-specific. The results suggest that both the generic and the sector-specific regimes are effective in enhancing financial and macroeconomic stability. A comparative effectiveness of the two policy regimes is shock dependent. The effectiveness of the two policy regimes is more or less the same when the economy faces a technology shock. However, the sector-specific regime outperforms the generic regime when one sector of the credit market is hit by a financial shock. On the contrary, the generic regime outperforms the sector-specific regime when the economy is hit by a housing demand shock that has similar spillover effects on household and corporate credit markets.

Chapter 4 develops and estimates a new Keynesian DSGE model, which features a stylised banking sector, a housing market and the role of monetary and macroprudential policies. The estimated model is then used to compare the effectiveness of a simultaneous deployment of monetary and macroprudential policies under the two alternative policy regimes against a benchmark regime in which there is only monetary policy. The first alternative regime is a combination of a standard monetary policy rule (Taylor rule) and a macroprudential policy rule, which is exemplified by a CcCR rule. The second alternative regime is a combination of an augmented monetary policy rule (an augmented Taylor rule), where the policy rate also reacts to credit growth, and a CcCR rule. The results suggest that a policy regime that combines a standard monetary policy and a macroprudential policy delivers a more stable economic system with price and financial stability. A policy regime that combines an augmented monetary policy and macroprudential policy is superior in enhancing financial stability, but compromises price stability.

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Chapter 2 has been accepted for publication in Economic Modelling. In this regard, I would like to thank the journal editor and an anonymous referee for valuable comments and suggestions. Chapter 3 has been published as a working paper of Economic Research Southern Africa (ERSA). It was also presented at the seminar series hosted by the Department of Economics at Stellenbosch University. I would also like to thank the Economics Society of South Africa (ESSA) for giving me an opportunity to present Chapter 4 at the 2019 biennial conference.

# Dedications

*This thesis is dedicated to my wife, my sons and my late parents.*

# Contents

<b>Declaration</b>	<b>i</b>
<b>Abstract</b>	<b>ii</b>
<b>Acknowledgements</b>	<b>iv</b>
<b>Dedications</b>	<b>v</b>
<b>Contents</b>	<b>vi</b>
<b>List of Figures</b>	<b>x</b>
<b>List of Tables</b>	<b>xii</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Housing and credit market shocks: Exploring the role of rule-based Basel III countercyclical capital requirements</b>	<b>7</b>
2.1 Introduction . . . . .	7
2.2 Stylised Facts: Financial variables, house prices and the business cycle in South Africa . . . . .	12
2.2.1 The data . . . . .	12
2.2.2 VAR Evidence . . . . .	13
2.3 The model . . . . .	16
2.3.1 The baseline model . . . . .	17
2.3.1.1 Households . . . . .	17
2.3.1.2 Entrepreneurs . . . . .	18
2.3.1.3 Banks . . . . .	20

2.3.1.4	Macroprudential policy . . . . .	23
2.3.1.5	Market clearing conditions and equilibrium . . . . .	23
2.3.2	The extended model . . . . .	24
2.3.2.1	Impatient Households (Borrowers) . . . . .	24
2.3.2.2	Entrepreneurs . . . . .	25
2.3.2.3	Banks . . . . .	25
2.3.2.4	Market clearing conditions . . . . .	26
2.4	Calibration . . . . .	26
2.5	Business cycle properties . . . . .	28
2.6	Rule-based Basel III countercyclical capital requirements . . . . .	30
2.6.1	Housing demand shock . . . . .	30
2.6.2	Loan repayment shock . . . . .	33
2.7	Optimal rules for implementing countercyclical capital buffers . . . . .	35
2.7.1	Countercyclical capital requirement rules . . . . .	36
2.7.2	Macroprudential authority loss function . . . . .	37
2.7.3	Optimal countercyclical capital requirement rules . . . . .	38
2.7.4	Constant vs. optimal rule-based countercyclical capital requirements . .	39
2.8	Conclusion . . . . .	42

### **3 The effectiveness of the countercyclical loan-to-value regulation: generic versus sector-specific rules 43**

3.1	Introduction . . . . .	43
3.2	The model . . . . .	48
3.2.1	Patient Households (Savers) . . . . .	49
3.2.2	Impatient Households (Borrowers) . . . . .	50
3.2.3	Entrepreneurs . . . . .	52
3.2.4	The bank . . . . .	54
3.2.5	Macroprudential policies . . . . .	57
3.2.6	Market clearing conditions and equilibrium . . . . .	58
3.3	Calibration . . . . .	58
3.4	Business cycle properties . . . . .	60
3.5	Optimal CcLTV rules: generic versus sector-specific . . . . .	62
3.6	Impulse response analysis . . . . .	64



3.6.1	Technology shock . . . . .	65
3.6.2	Financial (household loan loss) shock . . . . .	67
3.6.3	Housing demand shock . . . . .	69
3.7	Efficient policy frontier . . . . .	71
3.8	Implementing the CcLTV regulation: generic versus sector-specific rules . . . .	72
3.9	Conclusion . . . . .	75
<b>4</b>	<b>The optimal monetary and macroprudential policies for the South African economy</b>	<b>76</b>
4.1	Introduction . . . . .	76
4.2	The model . . . . .	81
4.2.1	Patient Households (Savers) . . . . .	82
4.2.2	Impatient Households (Borrowers) . . . . .	83
4.2.3	Entrepreneurs . . . . .	85
4.2.4	Retailers . . . . .	87
4.2.5	The bank . . . . .	88
4.2.6	Monetary policy . . . . .	90
4.2.7	Market clearing conditions and equilibrium . . . . .	91
4.3	Estimation . . . . .	91
4.3.1	Data . . . . .	91
4.3.2	Calibration . . . . .	93
4.3.3	Prior distributions . . . . .	95
4.3.4	Posterior estimates . . . . .	96
4.4	Business cycle properties . . . . .	97
4.5	Optimal monetary and macroprudential policy . . . . .	98
4.5.1	Policy loss function . . . . .	99
4.5.2	Policy regimes . . . . .	99
4.5.3	Optimal simple rules . . . . .	100
4.6	Impulse response analysis . . . . .	103
4.7	Efficient policy frontiers . . . . .	109
4.8	Conclusion . . . . .	111
<b>5</b>	<b>Summary</b>	<b>112</b>

<b>Appendices</b>	<b>115</b>
<b>A Housing and credit market shocks: Exploring the role of rule-based Basel III countercyclical capital requirements</b>	<b>116</b>
A.1 Complete set of equations for the baseline model . . . . .	116
A.2 Complete set of equations for the extended model . . . . .	118
A.3 Data and sources . . . . .	121
A.4 Results with the extended model: Rule-based Basel III countercyclical capital requirements . . . . .	122
A.3.1 Housing demand shock . . . . .	122
A.3.2 Loan repayment shock (impatient household) . . . . .	123
<b>B The effectiveness of the countercyclical loan-to-value regulation: generic versus sector-specific rules</b>	<b>126</b>
B.1 Complete set of equations for the model . . . . .	126
B.2 Data and sources . . . . .	129
B.3 Efficient policy frontier . . . . .	130
<b>C The optimal monetary and macroprudential policies for the South African economy</b>	<b>131</b>
C.1 Complete set of equations for the log-linearised model . . . . .	131
C.2 Data and sources . . . . .	135
C.3 Prior and posterior density plots . . . . .	137
C.3.1 Structural parameters . . . . .	137
C.3.2 Shock processes . . . . .	138
C.4 Monte Carlo Markov Chain (MCMC) multivariate convergence diagnostics . .	139
C.5 Model dynamics . . . . .	139
C.6 Historical decomposition . . . . .	142
C.7 Impulse response functions: entrepreneur LTV and NPL shocks under the three policy regimes. . . . .	144
C.7.1 Entrepreneur LTV shock . . . . .	144
C.7.2 Entrepreneur NPL shock . . . . .	146
<b>List of References</b>	<b>148</b>

# List of Figures

2.1	House prices, financial and key macroeconomic variables in S.A. . . . .	13
2.2	House prices, bank credit and bank capital in S.A. . . . .	14
2.3	VAR impulse responses to a negative shock on bank capital . . . . .	15
2.4	VAR impulse responses to a positive shock on house prices. . . . .	16
2.5	Impulse responses to a positive housing demand shock under alternative Basel regimes. . . . .	31
2.6	The effects of a positive housing demand shock under Basel II and III regimes. . .	32
2.7	Impulse responses to a negative loan repayment shock under alternative Basel regimes. . . . .	34
2.8	The effects of a negative loan repayment shock under Basel II and III regimes. . . .	35
2.9	Impulse responses to a positive housing demand shock: optimal macroprudential policy vs no macroprudential policy . . . . .	40
2.10	Impulse responses to a negative loan repayment shock (household borrower): optimal macroprudential policy vs no macroprudential policy . . . . .	41
3.1	Credit-to-output ratios in South Africa. . . . .	45
3.2	Impulse responses to a positive technology shock under the CcLTV regimes . . . .	66
3.3	Impulse responses to a negative household loan loss shock under the CcLTV regimes	68
3.4	Impulse responses to a positive housing demand shock under the CcLTV regimes .	70
3.5	The efficient policy frontier . . . . .	72
3.6	Policy response impact: generic CcLTV . . . . .	73
3.7	Policy response impact: household CcLTV . . . . .	74
3.8	Policy response impact: entrepreneur CcLTV . . . . .	74
4.1	Observable variables . . . . .	92
4.2	Impulse responses to a positive housing demand shock under different policy regimes	104

4.3	Impulse responses to a positive household LTV shock under different policy regimes	106
4.4	Impulse responses to a negative shock to household NPLs under different policy regimes . . . . .	108
4.5	The efficient policy frontiers: inflation vs credit-to-output ratio . . . . .	110
4.6	The efficient policy frontiers: inflation vs output . . . . .	111
A.1	Impulse responses to a positive housing demand shock under two Basel regimes . .	123
A.2	Impulse responses to a negative loan repayment shock (impatient household) under two Basel regimes . . . . .	124
B.1	Credit-output stability trade-off . . . . .	130
C.3.1	Prior and posterior marginal densities of structural parameters . . . . .	137
C.3.2	Prior and posterior marginal densities of shock processes . . . . .	138
C.4.1	MCMC multivariate convergence diagnostics . . . . .	139
C.5.1	Impulse responses to all shocks considered in this paper . . . . .	141
C.6.1	Historical decomposition of key variables . . . . .	143
C.7.1	Impulse responses to a positive entrepreneur LTV shock under the three policy regimes . . . . .	145
C.7.2	Impulse responses to a negative shock to entrepreneur NPLs under the three policy regimes . . . . .	147

# List of Tables

2.1	Calibrated parameters. . . . .	28
2.2	Business cycle properties. . . . .	29
2.3	Optimal countercyclical capital requirement rules. . . . .	39
3.1	Calibrated parameters. . . . .	59
3.2	Business cycle properties. . . . .	61
3.3	Optimal rules: generic versus sector-specific. . . . .	64
4.1	Calibrated parameters. . . . .	93
4.2	Prior and posterior distributions of the structural parameters. . . . .	96
4.3	Prior and posterior distributions of the shocks. . . . .	97
4.4	Business cycle properties. . . . .	98
4.5	Optimal policy parameters, welfare and standard deviations. . . . .	102

# Chapter 1

## Introduction

The financial crisis has highlighted that existing policies such as microprudential, monetary and fiscal policies are not enough to assure the safety of the financial system as a whole (Claessens, 2014, 3). It also became evident that bank capital regulatory framework adopted in 2004, Basel II capital regulation, is inherently flawed as it promotes pro-cyclicality in the financial sector (see for e.g., De Walque et al., 2010; Covas and Fujita, 2010; Angelini et al., 2010; Repullo and Suarez, 2013; Liu and Seeiso, 2012; Angeloni and Faia, 2013). The Basel II capital regulation enables banks to provide excessive credit in economic boom, but forces banks to sharply shrink credit in economic recession. This amplifies business cycle fluctuations, and has negative implications for financial and macroeconomic stability. It is against this backdrop that consensus emerged among world leaders to engage in financial sector reforms and move towards systemic orientated approach to financial regulation.

After the crisis, the Bank for International Settlements (BIS) introduced higher capital requirements, liquidity requirements, and caps on leverage under a new Basel III accord in the hope of strengthening financial institutions' resilience. To tackle the too-big-to-fail problem, systemically important financial institutions (SIFIs) are identified and are subjected to higher regulatory requirements, more intensive supervision, and resolution planning. In the derivatives markets, requirements are in place for trade reporting, central clearing, and margining. Other regulatory reforms include the development of the regulatory framework for shadow banking. In addition, the new regulatory framework provides what is called a "macroprudential overlay" to mitigate a build-up of systemic risk (Caruana, 2010). That is, the risk of disrupting provision of financial services due to the impairment of either parts of the financial system or the entire system with negative impact on the real economy (FSB-IMF-BIS, 2011). The main empha-

sis on systemic risk originates from the greater interconnectedness of the financial institutions, procyclical nature of the financial sector and its ability to amplify business cycle fluctuations.

From the policy perspective, there is now a consensus that financial regulation should start moving from micro-based approach towards macro-based approach. This culminated to the development of macroprudential policy framework as an overarching framework for financial regulation with well-defined policy tools. Consequently, the role of macroprudential policies emerged and gained prominence in policy discussions and academic research.<sup>1</sup> The main objective of macroprudential policies is to mitigate the build-up of financial systemic risk and reduce the macroeconomic cost of financial crises. The goal of macroprudential policies is to strengthen the resilience of the financial system against adverse shocks for greater financial and macroeconomic stability.

Macroprudential policies include tools and regulations aimed at addressing externalities and market failures within the financial system with the ultimate goal of financial stability (FSB-IMF-BIS, 2011). Cerutti et al. (2017) argue that macroprudential policies are mainly justified by the existence of externalities and market failures associated with financial sector activities which could lead to excessive pro-cyclicality and the build-up of systemic risk. These instruments include, but not limited to, capital-related instruments (e.g, countercyclical capital requirements and dynamic provisioning), liquidity-based instruments (e.g., liquidity coverage ratio, net stable funding ratio and reserve requirement ratio) and credit-related instruments (e.g., caps on loan-to-value and debt-to-income ratios, limits on credit growth and foreign currency lending). The intuition behind these policy instruments is to adjust them in a countercyclical manner to lean against financial cycles. During an economic boom, these policy instruments are tightened in order to dampen excessive credit growth and rapid increase in assets prices which could manifest into bubbles. This limits excessive leverage in the financial sector and contains the build-up of systemic risk. In economic downturn, when systemic risk has materialised, these instruments are relaxed in order to prevent rapid deleverage in the banking sector and asset price collapse. This mitigates the problem of credit squeeze and the spillover effects of financial distress to the real sector.

While there is consensus for the adoption of macroprudential policies, little is known about how these policies work (Bank of England, 2009; Hanson et al., 2011; Galati and Moessner,

---

<sup>1</sup> Although macroprudential policy gained prominence in the aftermath of the financial crisis, Clement (2010) note that its concept has been around since 1970's. Many of its tools have been used to supervise individual institutions (Jonsson and Moran, 2014).

2013; Claessens, 2014). The literature on their effectiveness, transmission channels, impact on financial sector and the real economy is still limited. The channels through which these policies work remain imperfectly understood. How these policies should be implemented still remains an open question. This is especially so in the context of emerging market economies (EMEs) such as South Africa. In general, the literature on the efficacy of macroprudential policies in building resilience of the financial sector and stabilising financial cycles is still in its infancy (Akram, 2014, 78). Some countries (where these policies have been used) have resorted on using them on an ad-hoc or experimental basis with limited appreciation of their effectiveness (Claessens, 2014, 3).

Furthermore, how macroprudential policy interacts with monetary policy, as their ultimate goals have implication for the overall stability of the economy, still remains an open question. This follows the move by many central banks around the world, including the South African Reserve Bank, to expand their mandate by adding an explicit objective of financial stability to the price stability objective in the aftermath of the financial crisis. The incorporation of macroprudential policy function into the central bank policy framework presents a new challenge for central banks regarding the coordination between monetary and macroprudential policies. This stems from the observation that the two policies do not affect economic conditions in isolation. In particular, the goals of monetary and macroprudential policies are mutually dependent. Their interaction extends from the consequences that failing to achieve the goal of one policy has for the difficulty of achieving the goal of the other. Parallel to this, is a renewed debate on whether monetary policy should also take into account the financial stability objective in addition to its primary objective of price stability. One strand of the literature documents that there are some stabilisation gains from allowing monetary policy to react to financial imbalances (e.g., Curdia and Woodford, 2010; Gambacorta and Signoretti, 2014; Verona et al., 2017; Adrian and Liang, 2018). These studies argue that monetary policy should aim to achieve the broader objective of overall economic stability rather than the narrower one of price stability alone. Another strand of the literature documents that there are no significant gains when allowing monetary policy to react to financial imbalances (e.g., Svensson, 2012; Gelain et al., 2013; Suh, 2014; Svensson, 2017; Turdaliev and Zhang, 2019). Specifically, these studies note that allowing monetary policy to respond to financial imbalances compromises price stability and therefore welfare detrimental. In a nutshell, while the greater emphasis on financial stability is welcomed, several questions still remain unanswered to improve our understanding on how macroprudential



policies work and their interaction with other policies such as monetary policy.

This thesis contributes to the ongoing research on macroprudential policies and their interaction with the monetary policy. The main goal of the thesis is to enhance our understanding on how macroprudential policies work; their effectiveness, transmission channels and their interaction with the monetary policy. The thesis also provides policy guidance on the optimal design and the implementation of macroprudential policies. This is particularly important as policymakers across the world are in the process of designing their own macroprudential policy frameworks.

The thesis' main objectives are three-fold. The first objective is to investigate the extent to which macroprudential policies dampen the fluctuations in financial and business cycles and contribute to greater financial and macroeconomic stability in the context of South Africa.<sup>2</sup> The second objective is to assess the effectiveness of various policy rules for implementing macroprudential policies with the ultimate goal of identifying appropriate design of macroprudential policies. The third objective is to study the interaction between macroprudential and monetary policies and its implications for financial and macroeconomic stability.

The thesis consists of three independent essays. The first essay develops a real business cycle dynamic stochastic general equilibrium (DSGE) model that features a stylised banking sector, a housing market and a role of a macroprudential authority in implementing Basel capital requirement regulations. The calibrated model is then used, firstly, to investigate the extent to which Basel III countercyclical capital requirements (CcCRs) attenuate fluctuations in credit and housing markets and mitigate the pro-cyclicality of Basel II bank capital regulation in the context of South Africa. To do this, a transition from Basel II to Basel III bank capital regulations is decomposed into two stages - the permanent increase of the capital requirement ratio (CRR) by 2.5% in line with the capital conservation buffer and the additional CcCR buffers. Secondly, the essay considers four different Basel III CcCR rules and compare their effectiveness in terms of enhancing financial and macroeconomic stability. The first CcCR rule says the authority should adjust CRR to credit-to-output gap in line with the recommendation by the Basel committee.<sup>3</sup> The second rule says CRR should respond to credit gap. The third rule

<sup>2</sup>Although financial stability is acknowledged as a primary objective of macroprudential policy, Galati and Moessner (2013) and Kahou and Lehar (2017) note that the literature is yet to establish a common ground on how to measure it. However, in this thesis financial stability is measured in terms of volatility of financial variables such as credit, credit-to-output ratio, house prices in line with Rubio and Carrasco-Gallego (2014) and Agénor and Pereira da Silva (2017).

<sup>3</sup>Throughout the thesis, credit-to-output gap refers to deviation of credit-to-output ratio from its steady-state. Other similar variables (output gap, credit gap etc.) are defined analogously.

says CRR should respond to credit and output gaps, whilst responding to credit, house prices and output gaps in the fourth rule. The results suggest that Basel III CcCRs are effective in attenuating fluctuations in the credit and housing markets and mitigating the pro-cyclicality of the Basel II capital regulation. The permanent increase in capital requirement ratio (a 2.5% conservation capital buffer) has a marginal impact in mitigating the pro-cyclicality of the Basel II capital regulation. The comparative assessment of four Basel III CcCR rules suggests that the most effective policy rule is the one in which the authority adjusts bank capital requirement ratio to credit and output gaps.

The second essay investigates the implications of the countercyclical loan-to-value (CcLTV) regulation in a setting where two types of borrowers (households and non-financial corporates) from distinct sectors of the credit market co-exist. To do this, the model framework developed in the first essay is extended to incorporate a role of a macroprudential authority in implementing household and non-financial corporate CcLTV regulations. We propose two policy regimes for implementing CcLTV regulations - one generic and one sector-specific - and compare their effectiveness in enhancing financial and macroeconomic stability. Under the generic regime, the authority adjusts the household and corporate LTV ratios to changes in aggregate credit and output whilst adjusting these ratios according to their specific sectoral credit conditions and output, with different intensities, under the sector-specific regime. The results suggest that both the generic and the sector-specific regimes are effective in enhancing financial and macroeconomic stability. A comparative assessment of the two policy regimes suggests that the effectiveness of these regimes is shock dependent. When the economy faces a technology shock, the effectiveness of the two policy regimes is more or less the same. However, when one sector of the credit market is hit by a financial shock, the sector-specific regime outperforms the generic regime in terms of enhancing financial and macroeconomic stability. On the contrary, the generic regime outperforms the sector-specific regime when the shock originating from the housing market (housing demand shock) affects the two sectors of the credit market.

The first two essays investigate the effectiveness and the implication of macroprudential policies in isolation of monetary policy. The third essay extends the analysis by examining the interaction between monetary and macroprudential policies in a framework where heterogeneous borrowers (households and non-financial corporates) co-exist. To do this, the essay develops and estimates a new Keynesian DSGE model, which features a stylised banking sector, a housing market and the role of monetary and macroprudential policies. Based on the

estimated model, the essay compares the effectiveness of a simultaneous deployment of monetary and macroprudential policies under the two alternative policy regimes against a benchmark regime in which there is only monetary policy. The first alternative regime is a combination of a standard monetary policy rule (Taylor rule) and a CcCR rule. The second alternative regime is a combination of an augmented monetary policy rule (an augmented Taylor rule), where the policy rate also reacts to financial variables, and a CcCR rule. The results suggest that a simultaneous deployment of monetary and macroprudential policies enhances financial and macroeconomic stability. The policy regime that combines a standard monetary policy and macroprudential policy is the most efficient policy regime and enhances both financial and macroeconomic stability. The regime that combines an augmented monetary policy and macroprudential policy is superior in enhancing financial stability, but compromises price stability.

The rest of the thesis is organised as follows. Chapter 2 examines the extent to which the Basel III bank capital regulation attenuates fluctuations in housing and credit markets, fosters financial and macroeconomic stability and mitigates the pro-cyclicality of Basel II bank capital regulation. Chapter 3 investigates the optimal design and the implications of the CcLTV regulations in a model economy where household and non-financial corporate borrowers co-exist. Chapter 4 investigates the optimal design and the effectiveness of monetary and macroprudential policies in promoting macroeconomic (price) and financial stability. Chapter 5 provides a brief summary of the thesis.

## Chapter 2

# Housing and credit market shocks: Exploring the role of rule-based Basel III countercyclical capital requirements<sup>1</sup>

### 2.1 Introduction

The recent financial crisis has highlighted that the Basel II regulatory framework is inadequate to safeguard the financial system as a whole. In fact, the Basel II bank capital regulation promotes excessive credit growth (excessive leverage in the private sector) in economic booms, which in turn can cause credit-induced asset price bubbles and increase the systemic vulnerability. When the risk materialises and the cycle reverses, the framework cannot enable banks to cope with adverse effects of negative financial shocks, forcing them into rapid deleverage and credit squeeze with dire consequences for the real economy. In short, one of the main shortcomings of this regulatory framework is pro-cyclicality.<sup>2</sup> Against this backdrop, consensus among world leaders emerged to adopt Basel III bank capital regulation with the overall objective of financial stability as part of comprehensive reforms on financial sector regulation.

The Basel III bank capital regulation introduces two main elements to enhance the resilience of the banking sector in periods of stress and mitigate the credit and housing boom-bust cycles, and the associate macroeconomic instability. First, over and above the 8% minimum capital

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<sup>1</sup>This chapter is published in Economic Modelling. See Liu and Molise (2019b).

<sup>2</sup>The framework requires banks to hold less capital in the upswing of the business cycle but more in the downswing. This in turn amplifies financial and business cycles and has negative implications for financial and macroeconomic stability. This is supported by Covas and Fujita (2010), Angelini et al. (2010), Liu and Seeiso (2012) and Repullo and Suarez (2013).

requirement of risk-weighted assets, the new regulation requires banks to hold a mandatory 2.5% capital conservation buffer. Second, to overcome the pro-cyclicality problem, it introduces a countercyclical capital buffer as macroprudential policy tool that acts as an automatic stabilizer. In economic boom (characterised by excessive credit growth and rapid increases in asset prices), banks are required to hold more capital. This in turn, limits excessive leverage in the banking sector and prevents the build-up of systemic vulnerability. In the downturn of the cycle (characterised by rapid decline in credit and asset prices), the buffer is released and banks hold less capital. That is, the regulation becomes more accommodating. This helps banks to cope with the shock (and cover for losses) and aid recovery, without jeopardising their ability to meet the regulatory requirement (BCBS, 2009).

Although the broader objective of the countercyclical capital buffer is clear<sup>3</sup>, its effectiveness, transmission mechanisms, and impact on the financial sector and the real economy remain imperfectly understood. This is especially the case in the context of emerging markets economies (EMEs) like South Africa. Most studies focus on developed countries (e.g., Angeloni and Faia, 2013; Angelini et al., 2014; Benes and Kumhof, 2015; Karmakar, 2016; Rubio and Carrasco-Gallego, 2016; Hollander, 2017) and little attention has been paid to EMEs. Furthermore, how to implement the countercyclical capital buffer still remains an open question. There is no consensus on the design of countercyclical capital buffer (the rule governing countercyclical capital requirements). For example, Angelini et al. (2014) consider the rule that responds to credit-to-output gap, Agénor et al. (2013) present the one reacting to deviations of the credit growth from its steady state, Rubio and Carrasco-Gallego (2016) propose the one reacting to credit gap while Karmakar (2016) introduces countercyclical capital rule that responds to output growth. Repullo and Saurina (2011) also criticise the design of countercyclical capital buffer based on credit-to-output gap and propose the use of output growth as a reference guide for taking buffer decisions. In South Africa, the Reserve Bank also raised concerns regarding the proposed countercyclical capital rule based on credit-to-output gap (SARB, 2011).<sup>4</sup> The Basel Committee on Banking Supervision (BCBS) provides only a reference guide as a starting point and encourages national authorities to use their own judgement when implementing the

<sup>3</sup>As in Basel Committee on Banking Supervision (2010), "The primary aim of the countercyclical capital buffer regime is to use a buffer of capital to achieve the broader macroprudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the build-up of system-wide risk."

<sup>4</sup>The argument is that the Basel III capital requirement, based on the credit-to-output ratio as a reference guide, has potential to exacerbate the pro-cyclicality of bank capital regulation, especially in countries where the credit-to-output ratio is negatively correlated with output.

tool.

The paper builds on the literature on the implications of Basel III capital requirements. A non-exhaustive list includes Angeloni and Faia (2013), Cecchetti and Kohler (2014), Angelini et al. (2014), Angelini et al. (2015), Benes and Kumhof (2015), Clerc et al. (2015), Lewis and Villa (2016), Karmakar (2016), Rubio and Carrasco-Gallego (2016) and Bekiros et al. (2018). The main conclusion from these studies is that Basel III countercyclical capital requirements (CcCRs) are effective in stabilising fluctuations in financial and macroeconomic variables and have potential to deliver financial stability and improve welfare. For instance, Clerc et al. (2015) and Karmakar (2016) show that higher capital requirements and the countercyclical capital buffer are effective in mitigating fluctuations in financial and business cycles and improving welfare. These findings are consistent with Repullo and Suarez (2013), Repullo (2013) and Gersbach and Rochet (2017), who provide the rationale for cyclically-adjusted capital requirements of Basel III. In particular, Repullo (2013) shows that cyclically-adjusted capital requirements mitigate credit squeeze and sharp decline in investment in the downswing of the business cycle. Gersbach and Rochet (2017) also document that CcCRs attenuate excessive credit fluctuations and could enhance social welfare. This paper is also related to Bekiros et al. (2018), in which the authors compare the effectiveness three alternative Basel III countercyclical capital rules (reacting to credit-to-output, credit gap, or credit growth) and establish that the countercyclical capital rule that reacts to credit gap is the most effective for enhancing banking stability and improving household welfare.

This paper contributes to the research on bank capital regulations in several ways. First, we decompose the transition from Basel II to Basel III into two stages, namely the permanent increase of the capital requirement ratio (CRR) by 2.5% in line with the capital conservation buffer and the additional countercyclical capital buffer. With this decomposition analysis, we investigate whether Basel III capital regulation is able to, and through which channels, attenuate the credit and housing markets boom-bust cycles and mitigate the pro-cyclicality of Basel II. This is in contrast to most studies, which focus on the interaction between Basel III capital requirements and monetary policy.<sup>5</sup> Secondly, we consider four different CcCR rules and compare their effectiveness in terms of financial and macroeconomic stabilisation benefits. We measure financial stability in terms of volatility of credit-to-output ratio and house prices and

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<sup>5</sup>See, for instance, Angeloni and Faia (2013), Cecchetti and Kohler (2014), Angelini et al. (2014), Angelini et al. (2015), Benes and Kumhof (2015), Lewis and Villa (2016) and Rubio and Carrasco-Gallego (2016).

macroeconomic stability with variability of output.<sup>6</sup> In contrast to Bekiros et al. (2018), the analysis in this paper also considers alternative policy rules that respond to house prices and output in addition to credit. The benchmark rule (rule A) says the regulatory authority should adjust the countercyclical capital requirement in response to the credit-to-output gap, in line with the BCBS guide. The second rule (rule B) says the CcCR should respond to the credit gap. The third rule (rule C) says the CcCR should respond to changes in credit and output gaps. The fourth rule (rule D) says the CcCR should respond to credit, house prices and output gaps. We argue that these rules capture the broad objective of macroprudential policy: financial stability without compromising macroeconomic stability. The third contribution is the use of a general equilibrium framework to evaluate the implications of Basel III bank capital requirements for the South African economy. To the best of our knowledge, this study is the first to do so.<sup>7</sup>

The main objective of this paper is to demonstrate the role of countercyclical capital buffers in attenuating fluctuations in credit and housing markets and mitigating the pro-cyclicality of Basel II. To achieve this objective, we develop a real business cycle dynamic stochastic general equilibrium (DSGE) model with a stylised banking sector and macroprudential authority.<sup>8</sup> Specifically, the model builds on the framework of Iacoviello (2015) and incorporates an explicit role of macroprudential policy along the lines of Rubio and Carrasco-Gallego (2016). Since this paper purely focuses on bank capital requirements and financial stability, the model abstracts from nominal rigidities. The model is calibrated to the real South African data. We consider the two sources of economic instabilities; a positive housing demand shock to mimic economic boom prior 2007 and a negative financial shock to capture the subsequent economic collapse post 2007 (see Fig. 2.1). While there are many factors behind the recent economic boom-bust cycle in South Africa, we only consider these two shocks to illustrate the role of Basel III bank capital requirements in mitigating the kind of credit and housing boom-bust cycles that marked the recent developments in South Africa.

The main findings of the paper are as follows. In comparison to Basel II capital regulation,

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<sup>6</sup>See for e.g., Rubio and Carrasco-Gallego (2014) and Agénor and Pereira da Silva (2017).

<sup>7</sup>The only related study on the South African economy is Liu and Seeiso (2012), in which the authors develop a DSGE model and study the impact of the Basel II bank capital regulation on business cycle fluctuations. Their results show strong evidence of the pro-cyclicality of Basel II.

<sup>8</sup>We are aware of some of the criticisms of DSGE models, especially for policy analysis in periods of distress. For example, Bekiros et al. (2016) postulate that this class of models fail to capture non-linearities inherent in data and are not good for calibration outside normal times. However, the objective of this paper is to illustrate the role of countercyclical capital buffers in dampening credit and house price cycles and mitigating the pro-cyclicality in the banking sector. We do not attempt to model crisis episodes per se.



Basel III CcCRs are effective in attenuating credit and housing market boom consequent upon housing demand shock. In fact, the increase in the regulatory requirements limits the extent to which banks can take on leverage and restrain credit supply in the economy. In this way, the new bank capital regulation can prevent potential credit and housing market bubbles and contain the build-up of systemic risk in an economic boom. By doing so, the regulation enhances financial and macroeconomic stability. We found that when the economy is hit by a negative financial shock (a credit and housing bubbles bust), the fall in the capital requirement ratio (the relaxation of the regulatory requirement) enables banks to better cope with the adverse effects of the shock without rapid deleverage. This mitigates the problem of credit squeeze in an economic downturn and reduces the severity of the recession. In contrast, the impact of a permanent increase in capital requirements (a 2.5% conservation capital buffer) has only marginal effects in attenuating fluctuations in the credit and housing markets and mitigating the pro-cyclicality of the Basel II capital regulation.

The comparison analysis of the four CcCR rules suggests that the most effective rule for enhancing financial and macroeconomic stability is rule C, the one in which the authority adjusts bank capital requirement ratio to changes in credit and output. The optimal implementation of this rule requires an aggressive response to changes in output and a stronger reaction to credit than that of rules A and B, in which the authority adjusts capital requirement ratio to changes in credit-to-output or credit only. The second best rule is rule D (in which the CcCR responds to credit, house prices and output), while rule B and rule A are ranked third and fourth, respectively. These rankings of the policy rules hold irrespective of whether the objective of the macroprudential authority is financial stability only or both financial and macroeconomic stability.

The rest of the paper is organised as follows. The next section highlights some stylised facts about the relationships between bank lending, house prices and the business cycle in South Africa. Section 2.3 describes the model in detail. Section 2.4 explains the calibration of the model and Section 2.5 explains business cycle properties of the model. In Section 2.6, we investigate the effectiveness of the new regulatory framework in attenuating the fluctuations in credit and housing markets and mitigating the pro-cyclicality of Basel II. Section 2.7 sets out the optimal rules for implementing countercyclical capital buffers. Section 2.8 concludes.



## 2.2 Stylised Facts: Financial variables, house prices and the business cycle in South Africa

This section presents the empirical evidence regarding the relationships between South Africa's house prices, financial and key macroeconomic data over the period 1994Q1 - 2016Q4.<sup>9</sup> We first highlight the co-movement between these variables and then provide a more formal analysis by considering the vector autoregressive (VAR) evidence on the impact of a positive house price shock and a negative bank capital shock. Both empirical exercises serve as references for the development and evaluation of the DSGE model in the paper.

### 2.2.1 The data

Fig. 2.1 shows the annual growth rates of bank credit, house prices and the key macroeconomic aggregates, such as household consumption and output (i.e., gross domestic product (GDP)). The upper panel in Fig. 2.1 shows the relationships between house prices, output and consumption. It is clear that house prices co-move closely with consumption and output, with house prices leading consumption and output growth. In particular, South Africa's housing boom period (2000 - 2006) is characterised by a sustained increase in house prices, consumption and output. During the 2007/08 financial crisis the trend reverses with the slowdown in house price inflation and subsequent decline in 2009, followed by a slowdown in consumption and output growth. Prior to 1998 and during the period 2010 - 2013, there is little (or no) indication of the co-movement between house prices and the two macroeconomic aggregates.

The lower panel in Fig. 2.1 highlights the relationships between house prices, consumption and household mortgage credit. It is evident that house prices and consumption move in tandem with mortgage debt over the sample period. This suggests that an increase in house prices generates wealth effects that enable home-owners to borrow more and spend more on consumption, particularly when they use housing wealth as collateral to secure credit. The increase in demand for consumption goods that follows an increase in house prices provides an incentive for firms to increase production. Hence the positive relationship between house prices and output observed in the upper panels in Fig. 2.1.

Fig. 2.2 shows the relationships between house prices and total mortgage credit (left hand

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<sup>9</sup>Data source: South African Reserve Bank (SARB).

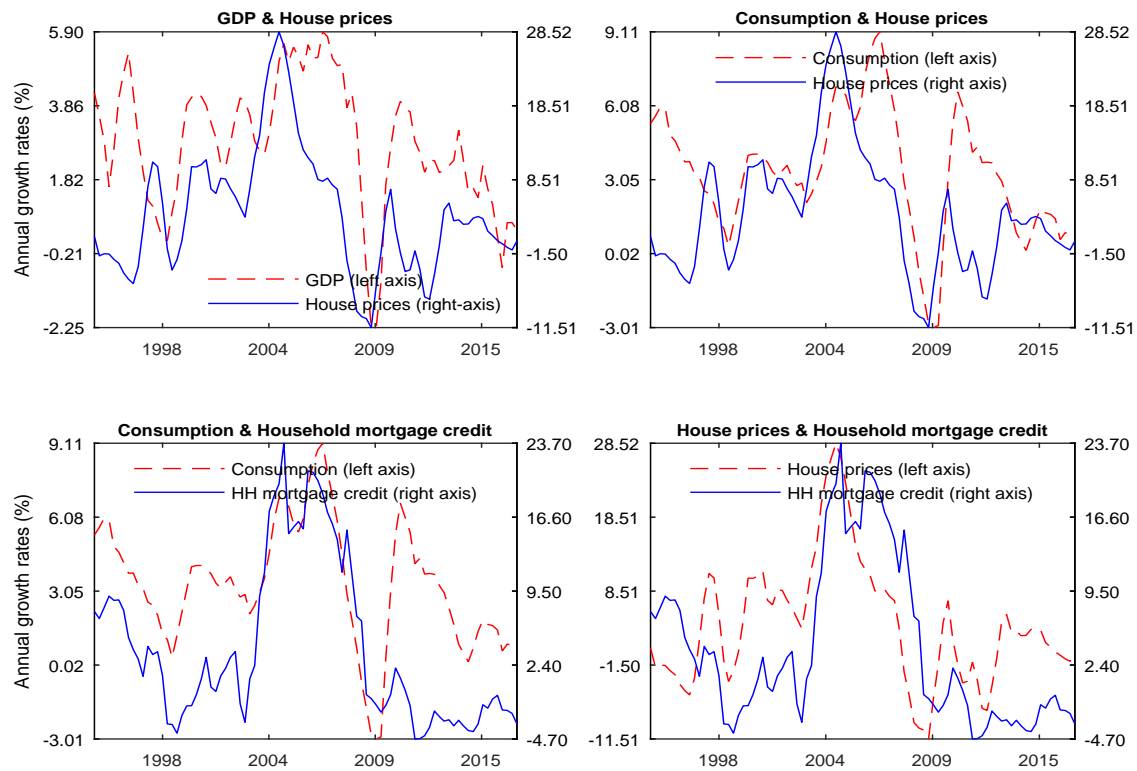


Figure 2.1: Relationships between house prices, financial and key macroeconomic variables in South Africa.

panel), and bank capital and total mortgage credit (right hand panel). It shows that house prices and mortgage credit move together closely, with house prices leading total mortgage debt. The only exceptional periods are prior to 1997 and the period 2012 - 2015, when the two series move in opposite directions. The right hand panel of Fig. 2.2 also provides evidence of the co-movement between bank credit and bank capital. Specifically, the co-movement between the two series is evident during the period 2002 - 2008. Prior to 2002 (the period associated with the 1997/98 Asian crisis) and during the post 2007/08 financial crisis period, the two series move in opposite directions. This suggests that during a crisis, while being restrained from lending, banks still need to take measures to replenish their capital to meet regulatory requirements.

## 2.2.2 VAR Evidence

In this section we establish empirically the extent to which bank capital and house price shocks shape the dynamics of the financial sector and the real economy. The empirical exercise serves as a reference for the development and evaluation of the DSGE model. We use a vector autoregressive (VAR) model which contains six variables: GDP, consumption, house prices, bank capital, the lending rate and the credit-to-output ratio over the sample period 1994Q1 to 2016Q4. We use share capital and reserves as measures for bank capital, and total mortgage credit to

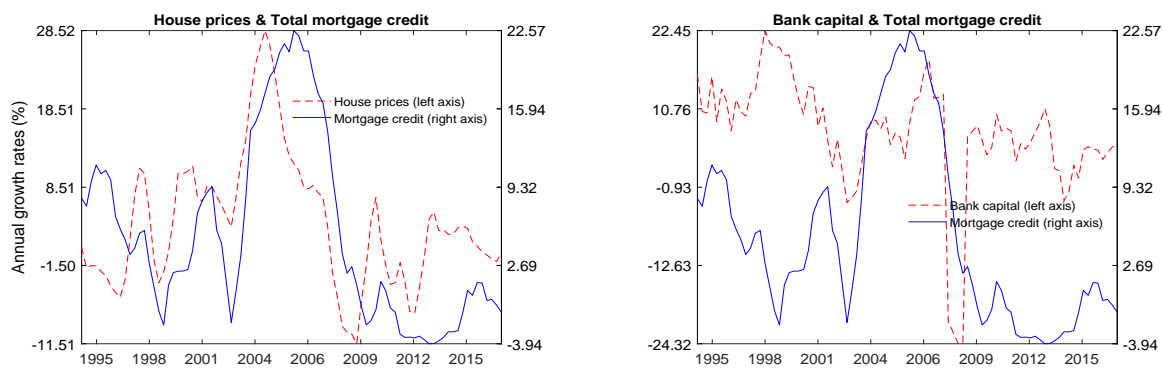


Figure 2.2: Relationships between house prices, bank credit and bank capital in SA.

households and non-financial corporates for bank credit. Nominal variables are deflated by the GDP deflator to get their real counterparts. The real interest rate is obtained by using the formula,  $r = (1 + R)/(1 + \pi) - 1$ , where  $r$  is the real interest rate,  $R$  is the nominal interest rate and  $\pi$  is the inflation rate measured by the annual percentage change in GDP deflator. To identify the system, we use Cholesky decomposition, ordering the variables as GDP, consumption, house prices, the lending rate, credit-to-GDP ratio and bank capital. Variables in the VAR system are in log-differences except for the lending rate. The VAR system includes up to 4 lags. The ordering of the variables is based on the assumption that real variables (GDP, consumption, house prices) do not respond contemptuously to shocks in financial variables (lending rate, credit-to-GDP ratio and bank capital), which is in line with Berrospide and Edge (2010) and Mésonnier and Stevanovic (2017). Different ordering schemes were explored in preliminary exercises, but these did not affect the results significantly.

We study the role of a bank capital shock in our empirical analysis for two reasons. First, the bank capital constraint (that ties bank lending to bank capital) plays a critical role in the transmission channel through which the banking sector interacts with the real sector. Second, since the macroprudential instrument (in this case, the capital requirement ratio) works to restrain or free banks' own available resources for lending, it is important to establish the impact of bank capital on bank lending. A negative bank capital shock serves as a proxy for loan repayment shock (financial shock), corresponding to unexpected increase in loan losses. In fact, unexpected increase in loan losses leads to a decline in banks' profits (retained earnings), and ultimately erodes bank capital.

Fig. 2.3 shows the impulse responses of the variables following a negative bank capital shock. Consistent with the literature, the results show that a negative bank capital shock reduces

credit-to-output ratio and leads to a fall in house prices, consumption and output.<sup>10</sup> Although these studies use different measures of bank capital (e.g., the capital-asset ratio), they establish that a negative bank capital shock induces banks to shrink their balance sheets and curtail credit with negative implications for real economic activity. The results suggest a negative relationship between banks' net worth (capital) and lending rates, and provide further evidence regarding the co-movements between bank capital, bank lending, house prices, consumption and output observed in Figs. 2.1 and 2.2.

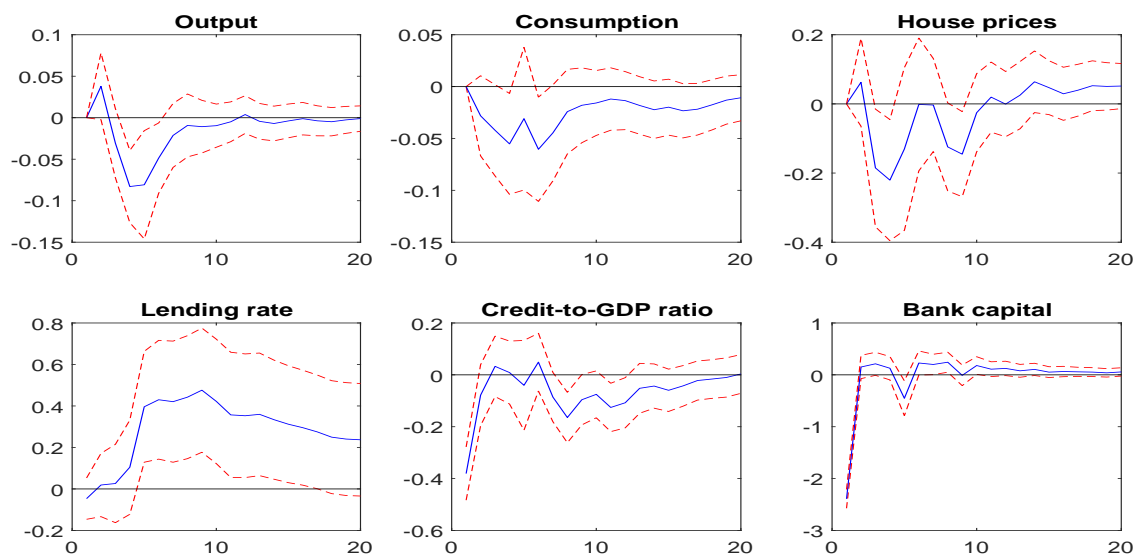


Figure 2.3: VAR impulse responses to a negative shock on bank capital. Note: red dashed lines represent one standard error bands.

Fig. 2.4 shows the impulse responses of the variables following a positive shock in house prices. The shock results in an increase in credit-to-output ratio, consumption and output. The same is also true for bank capital. The shock causes a temporary increase in the lending rate with the impact becoming negative 4 quarters after the shock occurs. In general, the results suggest that a positive shock in house prices has an expansionary impact on bank credit, consumption and output. These findings are consistent with the findings in the South African literature (see e.g., Aye et al., 2014; Apergis et al., 2014) and confirm the co-movement between house prices, bank lending, consumption and output highlighted in Figs. 2.1 and 2.2.

<sup>10</sup>See for e.g., Berrospide and Edge (2010), Michelangeli and Sette (2016), Mésonnier and Stevanovic (2017) and Kanngiesser et al. (2017)

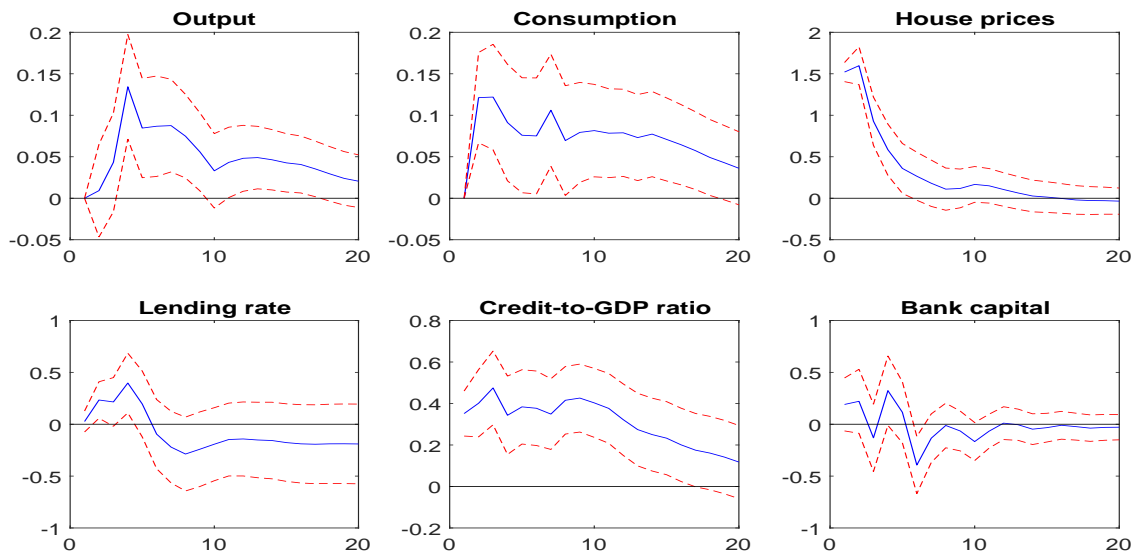


Figure 2.4: VAR impulse responses to a positive shock on house prices. Note: red dashed lines represent one standard error bands.

## 2.3 The model

The model framework is a closed economy real business cycle model featuring a banking sector, financial frictions and a macroprudential authority. Specifically, the model is built on the workhorse of Iacoviello (2015) and incorporates the role of a macroprudential authority in accordance with the Basel II and III capital regulatory frameworks following Rubio and Carrasco-Gallego (2016). In contrast to monetary business cycle models, the model abstracts from nominal rigidities. This is because the interest is not on the role of monetary policy or its interplay with countercyclical capital requirements (CcCRs). For similar studies on macroprudential policy that abstract from sticky prices, see Clerc et al. (2015), Karmakar (2016) and Hollander (2017). We keep the model simple, but sufficiently detailed to provide insights on how CcCRs contribute to financial and macroeconomic stability.

In this section, we first present the baseline model and lay out the transmission mechanisms through which housing demand and loan repayment shocks affect the financial sector and the real economy and the role of the rule-based CcCRs. The baseline model features three agents: households, entrepreneurs and banks (financial intermediaries). In this setup, we assume that households are the net savers in the economy while entrepreneurs are the net borrowers. In the subsequent section, we extend the baseline model and relax this assumption. Specifically, we introduce heterogeneity in the household sector and allow one group of households to be savers and the other to be borrowers. This helps us to capture some of the salient features of the South

Africa's economy described in sub-section 2.2.1 and affords a more realistic analysis of South Africa's housing market and mortgage credit market.

### 2.3.1 The baseline model

The model economy is populated by households, entrepreneurs and banks. Households consume final output and housing services, and supply labour to entrepreneurs. They are net savers in the economy and provide banks with funds in the form of savings deposits which earn a risk-free return. Entrepreneurs produce final output using labour and housing (commercial real estate) as inputs. To finance their production, entrepreneurs borrow funds from banks against their stock of housing wealth. Banks accept savings deposits from households (savers) and provide credit to entrepreneurs (borrowers). Banks are subject to a risk-weighted capital requirement. The macroprudential authority is responsible for setting bank capital requirements in line with Basel capital regulations.

#### 2.3.1.1 Households

The representative household chooses real consumption ( $C_{s,t}$ ), residential real estate or housing services ( $H_{s,t}$ ) and leisure ( $1 - N_t$ ) to maximize the expected discounted lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left[ (1 - \eta_s) \log(C_{s,t} - \eta_s C_{s,t-1}) + j A_t \log(H_{s,t}) + \tau \log(1 - N_t) \right], \quad (2.1)$$

where  $E_0$  and  $\beta_s \in (0, 1)$  denote the expectation operator and household's subjective discount factor, respectively.  $\eta_s$  measures the degree of external habit persistence for consumption. In line with Iacoviello (2015) and Guerrieri and Iacoviello (2017), the scaling factor  $1 - \eta_s$ , ensures that the marginal utility of consumption is independent of the habit parameter in the steady state.  $j$  and  $\tau$  are the weights of housing and leisure in the utility function, respectively.  $A_t$  denotes a housing demand shock that evolves according to the following law of motion:

$$\log(A_t) = \rho_a \log(A_{t-1}) + \xi_{a,t}, \quad 0 < \rho_a < 1, \quad (2.2)$$

where  $\rho_a$  is the persistence parameter of the shock process.  $\xi_{a,t} \sim i.i.d.N(0, \sigma_a^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_a^2$ . The housing demand shock captures exogenous factors which can shift households' preference and demand for housing.

Iacoviello (2005) suggests that the housing demand shock offers a parsimonious way to analyse exogenous disturbances on house prices.

In each period, the household begins with housing stock  $(H_{s,t-1})$  and savings deposits  $(D_{t-1})$  coming to maturity. Households also supply labour to entrepreneurs and receive a real wage rate  $W_t$ . Let  $R_{d,t}$  denote the real gross return on one-period risk-free deposits and  $q_t$  denote the relative price of housing (in units of consumption), the household's budget constraint is given by:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_t N_t + R_{d,t-1} D_{t-1}. \quad (2.3)$$

Let  $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t}-\eta_s C_{s,t-1}}$  be the marginal utility of consumption, the first order conditions for households' problem are as follows:

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \quad (2.4)$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \quad (2.5)$$

$$W_t = \frac{\tau}{(1 - N_t) U_{Cs,t}}. \quad (2.6)$$

Eq. (2.4) is the standard consumption Euler equation. Asset pricing equation (2.5) for housing equates the marginal cost of housing to its marginal benefit. For households, the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of housing service in units of consumption (marginal rate of substitution between housing and consumption) plus the present discounted value of housing (benefit housing provides in the next period as a store of wealth). Eq. (2.5) can also be regarded as households' demand function for housing. Labour supply condition (2.6) equates the real wage rate to the marginal rate of substitution between consumption and leisure.

### 2.3.1.2 Entrepreneurs

Entrepreneurs produce final output  $(Y_t)$  using labour  $(N_t)$  and housing  $(H_{e,t})$  as inputs. Housing (commercial real estate) includes retail, office and industrial properties. The representative entrepreneur maximizes the expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1 - \eta_e) \log(C_{e,t} - \eta_e C_{e,t-1}), \quad (2.7)$$

where  $\beta_e < \beta_s$  and  $C_{e,t}$  is the entrepreneur's real consumption. Since entrepreneurs are the owners of firms, their consumption can be regarded as profits or dividends payout. As such,  $\eta_e C_{e,t-1}$  captures some form of dividend smoothing in line with Liu et al. (2013). Liu et al. (2013) highlight that this form of dividend smoothing is essential to adequately explain the dynamics between asset prices and real variables. The budget constraint of the entrepreneur is given by:

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_t N_t + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \quad (2.8)$$

where  $L_{e,t}$  is the amount of loans borrowed from banks, which accrue real gross interest rate of  $R_{e,t}$ .  $AC_{le,t} = \frac{\phi_{le}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$  is the quadratic loan adjustment cost, where  $L_e$  is the steady-state value of  $L_{e,t}$ . This cost penalizes entrepreneurs for adjusting their loan portfolios rapidly between periods.

Following Iacoviello (2015), we introduce an exogenous loan repayment shock  $\zeta_{e,t}$ . Intuitively, the loan repayment shock can be thought of as partial defaults by borrowers on their loan contracts. The shock represents an income gain (increase in wealth) for borrowers. This is because by paying less than the contractual amount of loans, borrowers are able to spend more than previously anticipated. The same shock appears on the liability side of banks' balance sheet, but with a negative sign. For banks, this represents losses that banks incur when borrowers fail to honour their contractual obligations. The shock evolves according to the following law of motion:

$$\zeta_{e,t} = \rho_\zeta \zeta_{e,t-1} + \xi_{\zeta,t}, \quad 0 < \rho_\zeta < 1, \quad (2.9)$$

where  $\rho_\zeta$  is the parameter representing the persistence of the shock process.  $\xi_{\zeta,t} \sim i.i.d.N(0, \sigma_\zeta^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_\zeta^2$ .

Entrepreneurs also face the borrowing constraint:

$$L_{e,t} \leq m_e E_t \left( \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right). \quad (2.10)$$

Eq. (2.10) suggests that the total amount of credit entrepreneurs can secure from banks cannot exceed a fraction  $m_e$  of the expected market value of their collateral assets.  $m_e$  can be regarded as loan-to-value ratio associated to housing wealth. The dual role of housing as collateral asset and productive input is widely acknowledged in DSGE literature (see for e.g., Iacoviello, 2005; Chaney et al., 2012; Liu et al., 2013; Minetti and Peng, 2013). As will be shown later, the condition  $\beta_e < \beta_s$  ensures that the borrowing constraint (2.10) is binding in the neighbourhoods of the steady state.



Let  $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$  be the marginal utility of consumption and  $\lambda_{e,t}$  be the multiplier on the borrowing constraint (2.10), the first order conditions which define entrepreneurs' problem are as follows:

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \alpha \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) + m_e (\lambda_{e,t} / U_{Ce,t}) E_t \frac{q_{t+1}}{R_{e,t+1}}, \quad (2.11)$$

$$W_t N_t = (1 - \nu) Y_t, \quad (2.12)$$

$$1 - \frac{\phi_{le}}{L_e} (L_{e,t} - L_{e,t-1}) = \lambda_{e,t} / U_{Ce,t} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}. \quad (2.13)$$

Eq. (2.11) represents entrepreneurs' demand function for housing. It equates the marginal cost of one extra unit of housing (current price of housing) to its marginal benefits. For entrepreneurs, the marginal benefit of housing is given by the present discounted value of the next period's real return on housing plus the benefit of housing as a collateral asset for securing credit. Entrepreneurs' real return on housing is given by the marginal product of housing and future resale value of housing. Eq. (2.12) is the labour demand condition. Eq. (2.13) is the asset pricing equation for bank loans.

Production technology is given by a constant-return to scale Cobb-Douglas production function:

$$Y_t = Z_t H_{e,t-1}^\nu N_t^{1-\nu}, \quad (2.14)$$

where the parameter  $\nu \in (0, 1)$  is the elasticity of output with respect to housing. A technology shock ( $Z_t$ ) evolves according to the following law of motion:

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}, \quad 0 < \rho_z < 1, \quad (2.15)$$

where  $\rho_z$  is the persistence parameter of the shock process.  $\xi_{z,t} \sim i.i.d.N(0, \sigma_z^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_z^2$ .

### 2.3.1.3 Banks

Banks (financial intermediaries) mediate funds between savers (patient households) and borrowers (entrepreneurs). The representative bank chooses real consumption ( $C_{f,t}$ ) to maximize the expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1 - \eta_f) \log(C_{f,t} - \eta_f C_{f,t-1}), \quad (2.16)$$

where  $\beta_f$  denotes the bank's subjective discount factor. Note that  $C_{f,t}$  can be interpreted as profits generated by banks, which are assumed to be fully consumed by banks (as owners).  $\eta_f C_{f,t-1}$  represents some form of dividend smoothing. Banks' budget constraint is given by:

$$C_{f,t} + R_{d,t-1}D_{t-1} + L_{e,t} + AC_{ef,t} = D_t + R_{e,t}L_{e,t-1} - \zeta_t, \quad (2.17)$$

where  $D_t$  denotes households deposits,  $L_{e,t}$  is credit extended to entrepreneurs.  $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$  is the quadratic loan adjustment cost, reflecting costs associated with monitoring and redeeming existing loans and granting new ones.  $\zeta_t$  is the loan repayment shock that represents unexpected loan losses. From banks' perspective, loan losses represent a shock on their capital positions (bank net worth). An increase in loan losses reduces banks' profits and impairs their balance sheets. This results in a decline in bank capital. That said, the loan repayment shock can be regarded as a shock on bank capital.

Banks are subject to a capital requirement constraint in line with Basel capital regulations. Specifically, banks are required to hold a certain amount of bank capital that covers, at least, a specified fraction of their assets (loans). South African banks consistently maintain capital adequacy ratios over the regulatory requirements. Over the period 2008 - 2015, the average amount of bank capital held by South African banks is approximately 12% of risk weighted assets. For simplicity, the paper does not distinguish between required capital and excess capital held voluntarily by South African banks.

Let bank capital be  $BK_t = L_{e,t} - D_t - E_t\zeta_{t+1}$ , the capital adequacy constraint is given by:

$$\frac{L_{e,t} - D_t - E_t\zeta_{t+1}}{L_{e,t} - E_t\zeta_{t+1}} \geq \kappa_t, \quad (2.18)$$

where  $\kappa_t$  is the capital adequacy ratio (CAR). The capital adequacy constraint (2.18) can be rewritten and re-interpreted as a borrowing constraint as follows:

$$D_t \leq (1 - \kappa_t)(L_{e,t} - E_t\zeta_{t+1}). \quad (2.19)$$

Eq. (2.19) states that the amount of deposits that banks can take cannot exceed a fraction  $(1 - \kappa_t)$  of banks' assets net off the expected loan losses. The assumption  $\beta_f < \beta_s$  ensures that the constraint (2.19) is binding in the steady state. In the absence of this assumption, banks may find that it is optimal to postpone current consumption indefinitely and accumulate capital (through increasing in retained earnings) to the point where the capital requirement constraint does not have force.

Let  $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t}-\eta_f C_{f,t-1}}$  be the marginal utility of consumption and  $\lambda_{f,t}$  be the multiplier on the banks' borrowing constraint (2.19), the banks' optimal conditions for deposits and credit are given by:

$$1 - \lambda_{f,t}/U_{Cf,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t}, \quad (2.20)$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (\lambda_{f,t}/U_{Cf,t})(1 - \kappa_t) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}). \quad (2.21)$$

The banks' behavioural rule for taking deposits (2.20) suggests that the current period pay-off from taking one extra unit of deposit from households should equal the present discounted cost of raising such deposits from households. Eq. (2.21) equates the present discounted pay-off of providing one extra unit of credit to the marginal cost of providing such credit. It suggests that by reducing the pay-off, through reduction in credit and tightening the capital requirement constraint, banks can reduce next period's marginal cost of credit extension (in terms of foregone interest earning per unit of loan).  $\lambda_{f,t}/U_{Cf,t}$  is the utility cost of tightening the capital requirement constraint through credit reduction.

From Eqs. (2.20) and (2.21), the evaluation of the interest rate differential is given by:

$$R_{e,t+1} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[ \kappa_t (\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}) \right]. \quad (2.22)$$

Aside from portfolio adjustment costs, this condition implies that the presence of bank capital regulation creates a wedge between the lending rate and the deposit rate (marginal cost of funding in this case). In the absence of equity financing, banks need to accumulate retained earnings to meet higher regulatory requirement. As such, a high capital requirement creates incentive for banks to increase the credit spread and boost profits to meet the tighter regulatory requirement. Intuitively, Eq. (2.22) implies that banks pass the cost of capital regulation onto borrowers by requiring high compensation as the regulatory requirement becomes tighter.

Combining the steady state conditions of (2.4) and (2.20), we have

$$\lambda_f/U_{Cf} = \frac{\beta_s - \beta_f}{\beta_s} > 0. \quad (2.23)$$

That is, so long as banks are more impatient than households ( $\beta_f < \beta_s$ ), the borrowing constraint and the capital requirement constraint hold with equality at the steady state. Furthermore, with  $0 < \kappa < 1$ , in steady state the spread between the lending rate and the deposit rate is positive:

$$R_e - R_d = \frac{1}{\beta_f} (\lambda_f/U_{Cf}) \kappa > 0. \quad (2.24)$$

Using Eqs. (2.13), (2.21) and (2.23), the necessary condition for entrepreneurs' borrowing constraint to hold with equality is given by:

$$\frac{1}{\beta_e} > (1 - \kappa) \frac{1}{\beta_s} + \kappa \frac{1}{\beta_f}. \quad (2.25)$$

This implies that  $\beta_s > \beta_f > \beta_e$ .

### 2.3.1.4 Macprudential policy

Following Angelini et al. (2014), macroprudential policy is defined as follows:

$$\kappa_t = \kappa \left( \frac{L_t/Y_t}{L/Y} \right)^{\chi_x}, \quad (2.26)$$

where,  $\kappa$  is the steady state value of the capital adequacy ratio in accordance with the Basel capital regulation.  $L_t/Y_t$  and  $L/Y$  are the credit-to-output ratio and its steady-state value, respectively. The parameter  $\chi_x$  measures policy response to changes in credit-to-output gap, proposed by the Bank for International Settlements (BCBS, 2009).<sup>11</sup>

Eq. (2.26) can be regarded as a general specification for Basel capital regulation regimes since different values of  $\chi_x$  correspond to different regimes of the bank capital regulation.  $\chi_x = 0$  represents the case of fixed capital requirement ratio under Basel I. A negative value of  $\chi_x$  corresponds to the pro-cyclical Basel II, that is, the capital requirement ratio decreases in the upswing of business cycle and increases in the downswing. Lastly, setting  $\chi_x > 0$ , Eq. (2.26) represents the leaning-against-the-wind policy of the Basel III countercyclical capital buffer – promoting the build-up of capital buffers in good times, which can then be released in bad times.

### 2.3.1.5 Market clearing conditions and equilibrium

The economy's aggregate resource constraint is given by:

$$Y_t = C_{s,t} + C_{e,t} + C_{f,t} + Adj_t, \quad (2.27)$$

where  $Adj_t = AC_{le,t} + AC_{ef,t}$ .

The housing market clearing condition requires:

$$H_{s,t} + H_{e,t} = 1, \quad (2.28)$$

where the total supply of housing is fixed and normalised to one.

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<sup>11</sup>In the optimal policy analysis, we will consider alternative policy rules with different indicators.

### 2.3.2 The extended model

To gain more insight into the implications of Basel III CcCRs and capture some of the salient features of the South African economy as highlighted in sub-section 2.2.1, we extend the base-line model by introducing impatient households (borrowers) in the household sector. Impatient households use their housing wealth as collateral assets to secure credit from banks. The problem of patient households (savers) remains unchanged. This extension accommodates the fact that, over the period 1994 - 2016, the average share of household mortgage loans in total mortgage loans is approximately 77 percent.<sup>12</sup> It is, therefore, more realistic to have household borrowers in the model. In addition, there is growing evidence that house prices are important in explaining household consumption in South Africa (e.g., Apergis et al., 2014; Aye et al., 2014).

For the sake of brevity, the section only lays out additional features of the extended model: the problem of impatient households and the modified parts of the model for entrepreneurs and banks. The complete set of equations (including the first order conditions) for the extended version of the model is presented in appendix A.2.

#### 2.3.2.1 Impatient Households (Borrowers)

Analogous to patient households, impatient households maximise the present discounted value of the lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[ (1 - \eta_b) \log(C_{b,t} - \eta_b C_{b,t-1}) + j A_t \log(H_{b,t}) + \tau \log(1 - N_{b,t}) \right], \quad (2.29)$$

where  $\beta_b$  is impatient households' subjective discount factor, and  $\beta_b < \beta_s$ .  $C_{b,t}$  denotes real consumption,  $H_{b,t}$  is housing stock and  $N_{b,t}$  denotes impatient households' labour supply. Their budget constraint is given by:

$$C_{b,t} + R_{b,t-1} L_{b,t-1} + q_t (H_{b,t} - H_{b,t-1}) + AC_{lb,t} = W_{b,t} N_{b,t} + L_{b,t} + \zeta_{b,t}, \quad (2.30)$$

where  $L_{b,t}$  represents bank loans to impatient households which accrue a real gross interest rate of  $R_{b,t}$ .  $W_{b,t}$  is the real wage rate for impatient households.  $AC_{lb,t} = \frac{\phi_{lb}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_s}$  is the loan adjustment cost, assumed to be external to impatient households.  $\phi_{lb}$  denotes the adjustment cost parameter, whereas  $L_b$  is the steady-state value of  $L_{b,t}$ .  $\zeta_{b,t}$  is a household loan repayment

<sup>12</sup>The average share of household credit (mortgage loans plus other loans and advances) in total private sector credit from commercial banks is approximately 52 percent over the period 1994-2016.

shock that represents an indirect income gain (increase in wealth) for impatient households in the event of loan default.

Analogous to entrepreneurs, impatient households also face a credit constraint that limits the amount of borrowing to a fraction  $m_b$  of the expected value of housing wealth:

$$L_{b,t} \leq m_b E_t \left( \frac{q_{t+1}}{R_{b,t}} H_{b,t} \right). \quad (2.31)$$

### 2.3.2.2 Entrepreneurs

Entrepreneurs maximise the expected lifetime utility function,

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1 - \eta_e) \log(C_{e,t} - \eta_e C_{e,t-1}). \quad (2.32)$$

The budget constraint for entrepreneurs is now given by:

$$C_{e,t} + q_t (H_{e,t} - H_{e,t-1}) + R_{e,t} L_{e,t-1} + W_{s,t} N_{s,t} + W_{b,t} N_{b,t} + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \quad (2.33)$$

where  $N_{s,t}$  and  $N_{b,t}$  are patient and impatient households' labour supply, respectively.

Production technology (2.14) becomes:

$$Y_t = Z_t H_{e,t-1}^\nu [N_{s,t}^{1-\sigma} N_{b,t}^\sigma]^{1-\nu}, \quad (2.34)$$

where  $\sigma \in (0, 1)$  measures the share of impatient households labour income.

### 2.3.2.3 Banks

Banks maximise the expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1 - \eta_f) \log(C_{f,t} - \eta_f C_{f,t-1}). \quad (2.35)$$

The budget constraint (2.17) becomes:

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1} L_{b,t-1} + R_{e,t} L_{e,t-1} - \zeta_t, \quad (2.36)$$

where  $L_{b,t}$  and  $L_{e,t}$  are bank loans to impatient households and entrepreneurs, respectively.

$AC_{bf,t} = \frac{\phi_{bf}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_b}$  and  $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$  are quadratic loan portfolio adjustment costs associated with household and entrepreneur loans, respectively.  $\zeta_t = \zeta_{b,t} + \zeta_{e,t}$  is the loan repayment shock that represents loan losses that banks incur when impatient households and

entrepreneurs default. Let bank capital be  $BK_t = L_t - D_t - E_t\zeta_{t+1}$ , the capital adequacy constraint is given by:

$$\frac{L_t - D_t - E_t\zeta_{t+1}}{w_b L_{b,t} + w_e L_{e,t} - E_t\zeta_{t+1}} \geq \kappa_t, \quad (2.37)$$

where  $L_t = L_{b,t} + L_{e,t}$  is the total credit.  $w_b$  and  $w_e$  capture different degrees of risk associated with household and entrepreneur loans, respectively. The capital adequacy constraint (2.37) can be rewritten as a borrowing constraint as follows:

$$D_t \leq (1 - w_e \kappa_t)(L_{e,t} - E_t\zeta_{e,t+1}) + (1 - w_b \kappa_t)(L_{b,t} - E_t\zeta_{b,t+1}). \quad (2.38)$$

### 2.3.2.4 Market clearing conditions

The economy's aggregate resource constraint becomes;

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_t, \quad (2.39)$$

where  $Adj_t = \sum AC_{ij,t}$ . Aggregate resource constraint shows that final output is consumed and used to finance adjustment costs.

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \quad (2.40)$$

The total supply of credit is given by:

$$L_t = L_{b,t} + L_{e,t}. \quad (2.41)$$

## 2.4 Calibration

We calibrate the model to the South African economy over the sample period 1994Q1 - 2016Q4. Some of the parameters are calibrated using the real data to match steady state conditions of the model, while others are borrowed from the DSGE literature for EMEs.

Table 2.1 shows the calibrated parameter values for both the baseline and extended models. The discount factor for patient household (savers) is set at  $\beta_s = 0.991$  to match the South Africa's average real deposit rate of 3.5 percent (annualized) over the sample period. Following Iacoviello (2015), impatient households' and entrepreneurs' discount factors are calibrated at  $\beta_b = \beta_e = 0.94$ . The discount factor for banks is set at  $\beta_f = 0.945$ , which is lower than patient households' discount factor ( $\beta_s$ ) to guarantee that the capital adequacy constraints (2.18) and

(2.37) are binding in the neighbourhood of steady state.<sup>13</sup> The discount factors, together with the banks' leverage ratio (discussed below), are calibrated such that the borrowing constraints of impatient households and entrepreneurs hold with equality at steady state. These values also imply a spread of 200 basis points between the lending rate and the deposit rate, which is broadly in line with South Africa's interest rate data.

The share of housing in production is set at  $\nu = 0.1$  in the ballpark of the values widely used in the literature for EMEs (e.g., Iacoviello and Minetti, 2006). The housing weight in the utility functions is calibrated at  $j = 0.1$ . The choice of these values pins down the steady state ratio of housing wealth to output at 3.0 (annualized), of which 2.2 is residential housing wealth and 0.8 is commercial housing wealth. These ratios are fairly in line with the South African data on housing wealth.<sup>14</sup>

Leverage ratios for impatient households and entrepreneurs are set based on credit market data over the sample period. The loan-to-value (LTV) ratio for impatient households is set at  $m_b = 0.9$ . This value is fairly consistent with the minimum down-payment that South African banks require for providing home loans. In the case of entrepreneurs, LTV is set at  $m_e = 0.7$ . The choice of these values are well within the observed maximum LTV ratios for a first-time mortgage buyer typically found in emerging and developing economies, including South Africa. See for example IMF (2011). These values imply that the steady state ratio of household mortgage loans to total output is approximately 0.35, while the ratio of corporate credit to output is 0.53. The banks' leverage ratio is set to mimic Basel bank capital requirements; 0.08 under Basel II and 0.105 under Basel II.5 and III. For the values of the parameter governing macroprudential policy rule (2.26), see Section 2.6. The risk weights assigned to household and entrepreneur loans are both set at  $w_b = w_e = 1$ .

The weight on leisure in households' utility function  $\tau$  is set at 2, implying that households spend approximately one third of their time working. The impatient households' labour income share is calibrated at  $\sigma = 0.31$ , broadly in line with the estimated value of 0.27 in Gupta and Sun (2018) for the South African economy. Habit persistence for all agents is set at  $\eta = 0.7$ , which is broadly in line with the literature. Impatient households' and entrepreneurs' loan adjustment cost parameters are set at  $\phi_{lb} = \phi_{le} = 0.05$ . For banks, these parameters are calibrated at

<sup>13</sup>See section 2.3.1.3 for a detailed discussion on the conditions under which the capital adequacy constraint is binding in the steady state.

<sup>14</sup>The 2016 Property Sector Charter Council's (PSCC) report suggests that the share of South Africa's housing wealth to total output is approximately 2.3, 75 percent of which constituted residential housing wealth while the remaining is commercial housing. Source: <http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html>.



Table 2.1: Calibrated parameters.

Description	Parameter	Value	
		Baseline model	Extended model
Patient household discount factor	$\beta_s$	0.991	0.991
Impatient household discount factor	$\beta_b$	-	0.94
Entrepreneur discount factor	$\beta_e$	0.94	0.94
Bank discount factor	$\beta_f$	0.945	0.945
Habit persistence, $i = \{s, b, e, f\}$	$\eta_i$	0.70	0.70
Impatient household LTV ratio	$m_b$	-	0.90
Entrepreneur LTV ratio	$m_e$	0.70	0.70
Housing preference	$j$	0.10	0.10
Utility parameter for labor supply	$\tau$	2.0	2.0
Housing share in production	$\nu$	0.10	0.10
Impatient household income share	$\sigma$	-	0.31
Impatient household borrowing Adj. cost	$\phi_{lb}$	-	0.05
Entrepreneur borrowing Adj. cost	$\phi_{le}$	0.05	0.05
Bank loans to household Adj. cost	$\phi_{bf}$	-	0.05
Bank loans to entrepreneurs Adj. cost	$\phi_{ef}$	0.05	0.05
Risk weight (impatient household lending)	$w_b$	-	1.00
Risk weight (entrepreneurs lending)	$w_e$	-	1.00
Steady state Basel II CAR	$\kappa_{II}$	0.08	0.08
Steady state Basel II.5 & III CAR	$\kappa_{III}$	0.105	0.105
Autocorr. technology shock	$\rho_z$	0.95	0.95
Autocorr. housing demand shock	$\rho_a$	0.97	0.97
Autocorr. loan repayment shock, $j = \{b, e\}$	$\rho_{\zeta_j}$	0.90	0.90

$$\phi_{bf} = \phi_{ef} = 0.05.$$

Lastly, the persistence of the shocks are calibrated as follows. The autocorrelation coefficients for technology and housing demand shocks are set at  $\rho_z = 0.95$  and  $\rho_a = 0.97$  consistent with Liu and Gupta (2007) and the estimated value in Gupta and Sun (2018), respectively. The persistence of loan repayment shock is set at  $\rho_{\zeta_j} = 0.90$  (where,  $j = \{b, e\}$ ) based on the estimates in Iacoviello (2015).

## 2.5 Business cycle properties

This section assesses the business cycle properties of the baseline and extended models. Table 2.2 reports standard deviations of the main variables and their correlations with output implied by the baseline and extended models and those calculated from the actual data. For the model, the second moments are generated from a 1 percent productivity shock under the two Basel regimes.

Table 2.2: Business cycle properties.

Variable	Standard deviation (%)					Correlation with output				
	Data	Baseline model		Extended model		Data	Baseline model		Extended model	
		Basel II	Basel III	Basel II	Basel III		Basel II	Basel III	Basel II	Basel III
Output	1.16	1.29	1.23	1.11	1.06	1.00	1.00	1.00	1.00	1.00
Household consumption	1.76	1.18	1.12	1.09	1.03	0.81	0.99	0.99	0.99	0.99
House prices	4.59	2.00	1.89	1.60	1.53	0.30	0.80	0.80	0.89	0.89
Household deposits	2.77	5.84	4.46	4.38	3.26	0.23	0.86	0.88	0.86	0.91
Household loans	4.08	-	-	5.42	4.76	0.51	-	-	0.85	0.89
Corporate loans	4.81	5.64	4.67	3.58	2.67	0.31	0.82	0.83	0.88	0.91
Lending rate	0.83	0.42	0.67	0.58	0.77	-0.16	-0.50	-0.33	-0.11	-0.09

Data over 1994Q1 – 2016Q4 are obtained from the South African Reserve Bank (SARB). With the exception of lending rate, all variables are log-transformed and de-trended using HP filter.

The results show that the baseline and extended models reproduce the cyclical moments of the real sector fairly well. Standard deviations of output generated from both models are fairly close to the one observed from the data. The two models also do a reasonably good job in matching the standard deviation of consumption, but underestimate it to a certain extent. Both models underestimate the standard deviation of house prices, and this is particularly so for the extended model.

Both the baseline and the extended models reproduce variability of the lending rate which is fairly in line with the data, especially under Basel III. Though the baseline model somewhat exaggerates the volatility of deposits, the extended model reproduces it well in line with the data. This is particularly so under Basel III. The baseline model does a good job in replicating the standard deviation of corporate loans, whereas the model under Basel II slightly overestimates and the model under Basel III slightly underestimates it. The extended model also performs well in replicating standard deviations of household and corporate loans. Both the baseline and the extended models reproduce the fact that house prices, deposits and loans are more volatile than output, whereas the lending rate is less volatile than output.

The results further show that the baseline and extended models reproduce the co-movements between output and the main variables, which are fairly consistent with the data. Both models predict the positive correlation of output with consumption, house prices, deposits and loans, but overestimate these positive correlations. The baseline and the extended models also do a fairly good job in mimicking the negative correlation between the lending rate and output. While the extended model reproduces the negative correlation which is fairly in line with the data, the baseline model somewhat overestimates this negative correlation.

## 2.6 Rule-based Basel III countercyclical capital requirements

In this section, we investigate the extent to which the rule-based Basel III capital requirements dampen the fluctuations in the credit and housing markets and foster financial and macroeconomic stability. To do this, we decompose the transition from Basel II to Basel III capital requirement regime into two stages. The first stage entails a permanent increase in the capital adequacy ratio from 8% to 10.5%, in line with the conservative capital buffer. The second stage involves the introduction of a countercyclical capital buffer – the dynamic component of Basel III bank capital requirements.

To illustrate this transitional effect we compare model dynamics under the three regulatory regimes following a positive housing demand shock to mimic dynamics in economic boom and a negative loan repayment shock to mimic those in economic downturn.<sup>15</sup> The first regime corresponds to the Basel II capital requirement defined by  $\kappa = 0.08$  and  $\chi_x = -0.5$  to mimic the pro-cyclicality of Basel II regime. The second regime corresponds to the Basel II capital requirement plus the capital conservation buffer of 0.025, that is,  $\kappa = 0.105$  and  $\chi_x = -0.5$ . This can be regarded as the first stage of the transition from Basel II to Basel III and is referred to as Basel II.5. The third regime corresponds to the full implementation of Basel III, defined by setting  $\kappa = 0.105$  and  $\chi_x = 0.5$  to mimic the countercyclical buffer.

### 2.6.1 Housing demand shock

We first illustrate the results with a positive housing demand shock in Figs. 2.5 and 2.6. The shock increases house prices, and through the collateral channel, enables entrepreneurs to increase borrowing and stimulate production in the economy. To accommodate more lending, banks increase demand for deposits. Lending rates (credit spreads) also increase in response to higher demand for credit. All in all, the shock results in an increase in output and aggregate consumption.<sup>16</sup> These results are consistent with the VAR evidence reported in sub-section 2.2.2, suggesting that a positive house price shock has expansionary effects on the economy.

<sup>15</sup>Here we report the results for the baseline model only, whereas the results for the extended model are reported in appendix A.4.

<sup>16</sup>Aggregate consumption is the sum of households', entrepreneurs' and banks' consumption. That is,  $C_t = C_{s,t} + C_{e,t} + C_{f,t}$ .

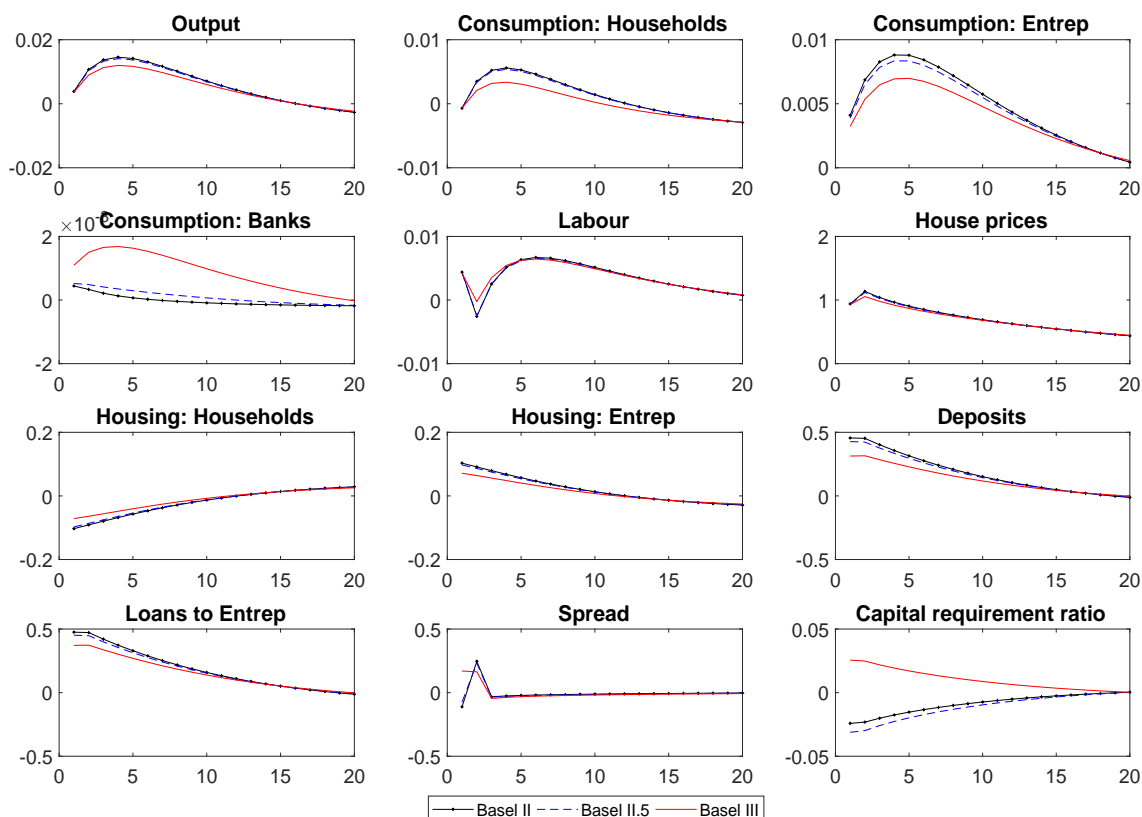


Figure 2.5: Impulse responses to a positive housing demand shock under alternative Basel regimes. Notes: Black asterisk line: Basel II; Blue dashed line: Basel II.5; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points. Entrep stands for entrepreneur.

The black asterisk lines in Fig. 2.5 illustrate the impact of the shock under the Basel II regime while the right hand side of Fig. 2.6 summaries the transmission channel graphically. In this case, bank capital requirement ratio declines when credit-to-output ratio increases.<sup>17</sup> This creates scope for banks to extend more credit and amplify the initial impact of the shock on house prices, consumption and output. In fact, the fall in capital requirement ratio promotes excessive credit growth, which may leads to the formation of credit-induced house price bubbles and threatens financial stability.

The blue dotted lines and red solid lines in Fig. 2.5 illustrate the impact of a 2.5% permanent increase in capital requirement ratio (conservation buffer) and countercyclical capital buffer, respectively. The decomposition analysis of the transition to Basel III suggests that the countercyclical capital buffer significantly mitigates the pro-cyclical effects of Basel II, whereas the attenuation effect of the conservation buffer (Basel II.5) is marginal. Under the Basel III

<sup>17</sup>The reasoning is as follows. Under the internal ratings based (IRB) approach of Basel II, bank capital requirement ratio increases with the riskiness of the loan portfolio. Since this riskiness is negatively related to the credit (business) cycle, banks are required to hold less capital in the upswing of the credit (business) cycle when the credit risk is lower and more in the downswing when the risk is higher.

regime, the macroprudential authority increases capital requirement ratio when the credit-to-output ratio increases. This forces banks to adjust their balance sheets and curtail credit growth to meet the higher regulatory requirements.<sup>18</sup> In addition to this first round effect stemming from the quantitative restriction on the volume of lending, tighter capital requirements also lead to an increase in lending rates (credit spreads). This in turn works to curtail demand for credit. Consequently, the extent of an increase in credit, house prices, aggregate consumption and output is smaller under the Basel III regime than under the Basel II regime. The left hand side of Fig. 2.6 summarises this transmission mechanism.

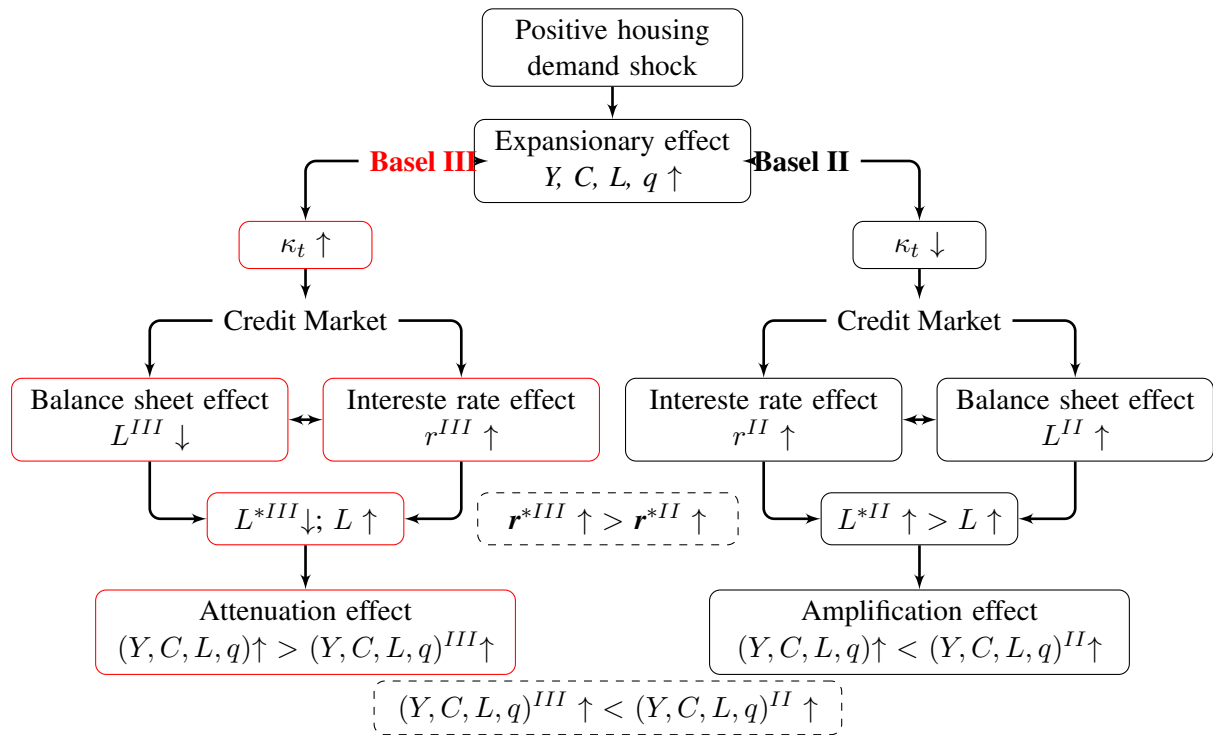


Figure 2.6: The effects of a positive housing demand shock under Basel II and III regimes. *Note:* An up arrow indicates an increase while a down arrow denotes a fall in a variable. The notations for the variables are as in the paper. The superscript II and III denote Basel II and III regimes.

In brief, the results show that Basel III CcCRs are effective in attenuating credit and housing markets boom following a housing demand shock. In this way, the new regulatory framework can prevent potential credit and housing market bubbles and contain the build-up of systemic risk. This promotes financial stability and contributes to the achievement of macroeconomic stability. Furthermore, we observe that the Basel III bank capital regulation has asymmetric effects across economic agents. The new regulation generates countercyclical effects on patient

<sup>18</sup>Banks can also meet higher regulatory requirement by either increasing capital through a reduction in consumption. However, this option is ruled out by the assumption made earlier that banks are relatively impatient.

households' and entrepreneurs' (borrowers) consumption, but pro-cyclical with respect to that of banks.<sup>19</sup> The fall in credit supply reduces borrowers' ability to finance investment in production. This in turn, leads to a moderate increase in households' and entrepreneurs' income (relative to the Basel II regime). Consequently, their consumption and hence output do not increase as much as under Basel II regime.

## 2.6.2 Loan repayment shock

Fig. 2.7 shows the impulse responses of the main variables to a negative loan repayment shock, corresponding to an unexpected increase in loan losses on entrepreneurs' loans. The shock reduces banks' net worth (capital). This forces banks to reduce credit supply and increase lending rates (credit spread) in order to meet the regulatory requirement. The fall in credit supply and higher lending costs induce entrepreneurs to reduce investment in housing. This decline in entrepreneurs' demand for housing drives down house prices. Consequently, output and aggregate consumption decrease while entrepreneur consumption increases. The increase in entrepreneur consumption is due to the income gain as the consequence of default. These results concur with the finding by Iacoviello (2015) that a negative loan repayment shock has recessionary effects. Furthermore, the results conform with the VAR evidence on the impact of a negative shock on bank capital (see sub-section 2.2.2).

The black asterisk lines in Fig. 2.7 and the right hand side of Fig. 2.8 illustrate the impact of a negative financial shock under Basel II regime. In this case, bank capital requirement ratio increases because of a recession (a fall in credit-to-output ratio).<sup>20</sup> This in turn forces banks to curtail the supply of credit further and exacerbate the initial impact of the shock on credit, house prices, aggregate consumption and output.

The transition towards higher capital requirements (Basel II.5) plays a negligible role in attenuating the impact of the shock and the pro-cyclical of the Basel II regime on financial and real variables. It is the full implementation of Basel III, particularly the introduction of countercyclical capital buffers, that has pronounced effect in mitigating the negative impact of the shock. Under the Basel III regime (red solid lines in Fig. 2.7 and the left hand side of Fig. 2.8), the fall in the credit-to-output ratio triggers capital requirement ratio to decline. This

<sup>19</sup>While the results of banks' consumption may look counter-intuitive, it is important to highlight that this is due to the model set-up. Since there is no other investment opportunity for banks in this model set-up, a higher capital requirement forces banks to accumulate more capital (financial resources), which they ultimately consume.

<sup>20</sup>As mentioned earlier, under Basel II regime banks are required to hold more capital when credit risk materialisation is high (typically in recession) and less when the risk is low (in economic boom).

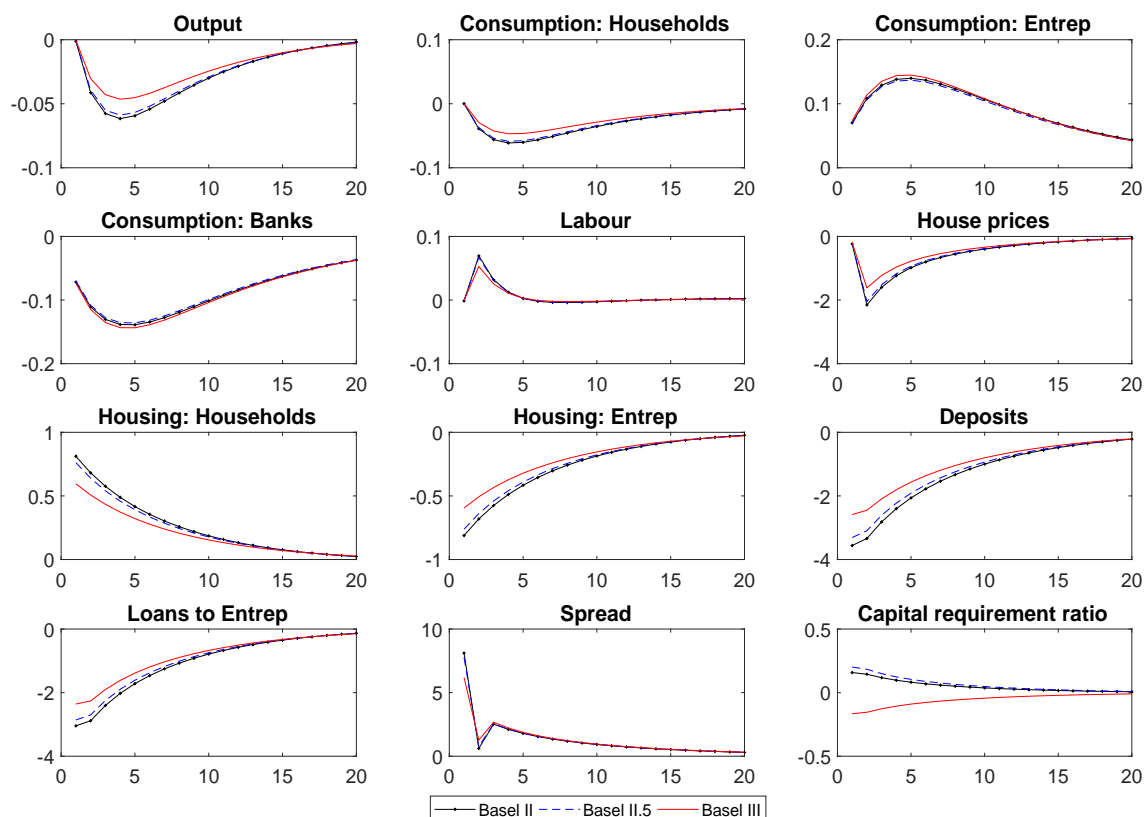


Figure 2.7: Impulse responses to a negative loan repayment shock under alternative Basel regimes. Notes: Black asterisk line: Basel II; Blue dashed line: Basel II.5; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points. Entrep stands for entrepreneur.

reduces pressure on banks to deleverage rapidly and increase lending rates more. In fact, the drop in credit supply and the increase in lending rate are less drastic under Basel III than under Basel II. As a result, the extent of the fall in house prices, aggregate consumption and output becomes smaller under Basel III regime.

In general, the results suggest that Basel III regime (particularly countercyclical capital buffer) is effective in mitigating the negative effects of the financial shock. The relaxation of the regulatory requirements, in economic downswing, enables banks to better cope with the adverse effects of the shock without rapid deleverage. This mitigates the problem of credit squeeze and a sudden collapse of asset prices when the economy is hit by a negative shock. In this way, the new regulation can help to reduce the severity of economic recession and contribute to economic stability. The results are consistent with other studies (e.g., Angeloni and Faia, 2013; Angelini et al., 2014; Benes and Kumhof, 2015; Karmakar, 2016; Rubio and Carrasco-Gallego, 2016), which show that Basel III bank capital requirements are effective in attenuating the pro-cyclical effects of the Basel II framework, particularly when the economy is hit by financial shocks. The results also highlight that the new regulation generates pro-cyclical

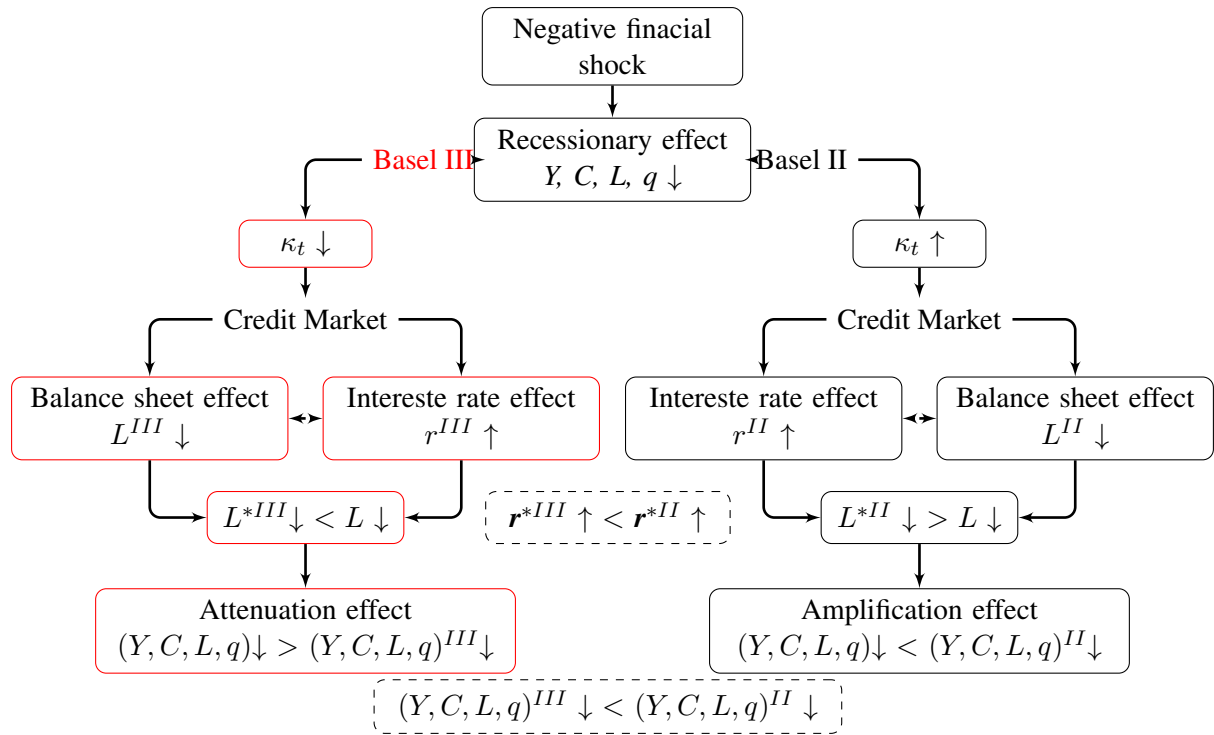


Figure 2.8: The effects of a negative loan repayment shock under Basel II and III regimes. *Note:* An up arrow indicates an increase while a down arrow denotes a fall in a variable. The notations for the variables are as in the paper. The superscript II and III denote Basel II and III regimes.

effects with respect to banks' and borrowers' consumption, but countercyclical with respect to patient households' consumption.

Although the focus of the study is on the stabilisation effects of countercyclical capital requirements, it is important to note that tighter regulatory requirements could reduce the potential level of bank lending, which in turn reduces economic activity. As such, there will be welfare cost implications.

## 2.7 Optimal rules for implementing countercyclical capital buffers

Having established that the rule-based Basel III bank capital requirements are effective in attenuating fluctuations in housing and credit markets and have potential to foster financial stability, to complete our analysis, we now address the question relating to the design and implementation of countercyclical capital buffer.<sup>21</sup> We consider four policy rules for setting countercyclical capital buffers and examine their effectiveness in enhancing financial stability and to the extend

<sup>21</sup>This issue still remains an open question in the literature. See Section 2.1 for a detailed discussion of this.



possible macroeconomic stability. We use the volatility of credit-to-output ratio and house prices as the measures of financial stability. This is consistent with the literature, which suggest that excessive credit-to-output growth and asset price booms are often associated with financial distress (e.g., Schularick and Taylor, 2012; Mallick and Sousa, 2013; Aikman et al., 2015). On the other hand, macroeconomic stability is measured by output volatility.

### 2.7.1 Countercyclical capital requirement rules

The benchmark rule (rule A) is given by the macroprudential policy rule (2.26), in line with the BCBS proposal. That is:

$$\kappa_t = \kappa \left( \frac{L_t/Y_t}{L/Y} \right)^{\chi_x}, \quad (2.42)$$

where  $L$  and  $Y$  are steady-state values of credit and output, respectively.  $\chi_l > 0$  measures policy's response to changes in the credit-to-output gap. The first alternative rule (rule B) assumes that the regulatory authority adjusts capital requirement ratio in response to changes in credit relative to its steady state:

$$\kappa_t = \kappa \left( \frac{L_t}{L} \right)^{\chi_l}, \quad (2.43)$$

where  $\chi_x > 0$  measures policy's response to changes in the credit gap. In rule C, the regulator adjusts capital requirement ratio in response to deviations of credit and output from their steady states:

$$\kappa_t = \kappa \left( \frac{L_t}{L} \right)^{\chi_l} \left( \frac{Y_t}{Y} \right)^{\chi_y}, \quad (2.44)$$

where  $\chi_l > 0$  and  $\chi_y > 0$  measure policy's response to changes in credit and output gaps, respectively. In rule D, capital requirement ratio is reacting to deviations of credit, house prices and output from their steady states:

$$\kappa_t = \kappa \left( \frac{L_t}{L} \right)^{\chi_l} \left( \frac{Y_t}{Y} \right)^{\chi_y} \left( \frac{q_t}{q} \right)^{\chi_q}, \quad (2.45)$$

where  $q$  is the steady-state value of house prices and the coefficients  $\chi_l > 0$ ,  $\chi_y > 0$  and  $\chi_q > 0$  measure policy's response to changes in credit, output and house prices gaps, respectively.

The three alternative rules (Rules B, C and D) capture the intuition behind the Basel III countercyclical capital buffer: to protect the banking sector from excessive fluctuations in credit, which could have negative implications for financial stability. In rule C, the authority also consider the cyclical position of the economy when setting countercyclical capital buffer.

In the case of South Africa, where the regulator is concerned not only about excessive fluctuations in credit but also fluctuations in asset prices (e.g., house prices), rule D seems to be the suitable option. In a way, the three alternative policy rules can be thought of as attempts to address some of the critics of the countercyclical rule, especially the use of the credit-to-output ratio as a reference guide for taking buffer decisions.

## 2.7.2 Macprudential authority loss function

In order to make a concise comparison between the four policy rules, we use a standard (frequently used) criterion, whereas the main objective of the authority is to minimise volatilities in key policy variables: primarily, the credit-to-output ratio, asset prices and output in the case of macroprudential authority. Along the lines of Angelini et al. (2014), we define the macroprudential authority's loss function as follows:

$$\mathcal{L}_{mp} = \sigma_x^2 + \lambda_q \sigma_q^2 + \lambda_y \sigma_y^2 + \lambda_\kappa \sigma_\kappa^2, \quad (2.46)$$

where  $\sigma_x^2$ ,  $\sigma_q^2$ ,  $\sigma_y^2$  and  $\sigma_\kappa^2$  are the unconditional variances of credit-to-output ratio, house prices, output and the capital requirement ratio (macroprudential instrument), respectively. The parameters  $\lambda_q \geq 0$ ,  $\lambda_y \geq 0$  and  $\lambda_\kappa \geq 0$  represent the relative weights on the variabilities of house prices, output and the policy instrument in the loss function. Consistent with the broad objective of macroprudential policy, the aim of the authority is to reduce systemic risk by stabilising fluctuations in credit and to the extent possible excess volatility in asset prices (house prices) and output. In essence, the loss function (2.46) implies that the macroprudential authority strives to achieve financial stability (measured by fluctuations in credit and house prices) without compromising macroeconomic stability (measured by output fluctuations). The inclusion of  $\sigma_\kappa^2$  in the loss function is warranted by the notion that the authority may want to avoid undue fluctuations in the policy instrument (Angelini et al., 2014). To simplify our analysis, we set  $\lambda_\kappa = 0.1$  and conduct the experiments with different values of the relative weights on house prices and output within the following ranges:  $\lambda_q = [0, 0.5]$  and  $\lambda_y = [0, 0.5]$ .<sup>22</sup> For each combination of the loss function weights, we compute the optimal policy parameters  $(\chi_x^*, \chi_l^*, \chi_q^*, \chi_y^*)$

<sup>22</sup>The assignment of the relatively lower weight on house prices in the loss function is also consistent with the empirical evidence suggesting that fluctuations in credit is relatively more important than asset prices in predicting financial instability and financial distress (Agénor and Pereira da Silva, 2017). As such, the authority may want to assign higher weight on credit than on asset prices.

in Eqs. (2.42) to (2.45) that minimise the loss function (2.46) subject to the constraints given by the model.<sup>23</sup>

### 2.7.3 Optimal countercyclical capital requirement rules

Table 2.3 shows the optimal parameters for each of the four policy rules together with the values of the objective function under the four different weighting schemes.<sup>24</sup> In column three, we assume that the authority only cares about fluctuations in credit. In columns four and five, the assumption is that the authority also attaches some weights on the stabilisation of either output (column four) or house prices (column five). The last column corresponds to the case where the authority not only cares about financial stability but also macroeconomic stability. In fact, columns three and five are consistent with the financial stability objective with different degrees of house prices stabilisation, while the fourth column and the last column take into account both financial and macroeconomic stability.

The results suggest that moving from rule A to rule B (the CcCR rule responding to changes in credit only) reduces welfare loss. When the authority follows rule C and adjusts the policy instrument to changes in credit and output, the loss function value decreases tremendously. The optimal implementation of rule C requires aggressive response to changes in output (as indicated by a big value of  $\chi_y$  compared to  $\chi_x$  and  $\chi_l$ ) and a strong reaction to credit ( $\chi_l^{RuleC} > \chi_l^{RulesA} > \chi_x^{RulesB}$ ). Moving from rule C to rule D results in a slight increase in welfare loss. This implies that the inclusion of house prices in the macroprudential policy reaction function (rule D) does not necessarily enhance the effectiveness of the policy. However, under rule D the authority does not need to respond to changes in output as aggressively as under rule C:  $\chi_y$  decreases significantly under rule D. The results indicate that rules C and D are more effective in stabilising the loss function of macroprudential authority than rules A and B, in which the authority reacts solely to a measure of credit (either credit or credit-to-output). That is, the inclusion of output (and house prices) in the policy rule enhances the effectiveness of macroprudential policy.

In the nutshell, the results show the most effective policy rule for fostering financial and macroeconomic stability is the one in which the authority adjusts capital requirement ratio to

<sup>23</sup>We conduct the optimisation exercise using the extended model. This is because the extended model is more detailed than the baseline model and therefore provides more insights on the implications of countercyclical capital requirements.

<sup>24</sup>To perform the optimisation exercise, we use optimal simple rule (osr) optimisation routine in Dynare.

Table 2.3: Optimal countercyclical capital requirement rules.

Policy rule	Parameter	Optimal policies: weighting scheme $(\lambda_\kappa, \lambda_q, \lambda_y)$			
		(0.1, 0.0, 0.0)	(0.1, 0.0, 0.5)	(0.1, 0.5, 0.0)	(0.1, 0.5, 0.5)
<b>Policy rule A</b>	$\chi_x$	0.7138	0.7138	0.7138	0.7138
Loss function value		0.0151	0.0151	0.0208	0.0209
<b>Policy rule B</b>	$\chi_l$	0.7164	0.7164	0.7164	0.7164
Loss function value		0.0124	0.0124	0.0179	0.0179
<b>Policy rule C</b>	$\chi_l$	0.7392	0.7394	0.7411	0.7410
	$\chi_y$	6.3252	6.3391	6.8040	6.8057
Loss function value		0.0018	0.0019	0.0058	0.0058
<b>Policy rule D</b>	$\chi_l$	0.7542	1.0206	0.7575	0.7582
	$\chi_y$	2.0698	1.9372	2.2482	2.2474
	$\chi_q$	3.2280	2.9895	3.4587	3.4574
Loss function value		0.0021	0.0019	0.0062	0.0062

changes in credit and output (rule C). These results hold irrespective of whether the objective of the authority is financial stability only (columns three and five in Table 2.3) or both financial and macroeconomic stability (columns four and six). It is worth noting that the inclusion of house price stabilisation objective (columns five and six) requires a more aggressive response to changes in output and house prices (compare column three with column five and column four with column six). Taking the house price stabilisation objective into account significantly increases the value of the loss function. This in turn requires an aggressive policy response to stabilise the loss function. On the other hand, the optimal coefficients on credit and credit-to-output remain virtually unchanged across the weighting schemes..

#### 2.7.4 Constant vs. optimal rule-based countercyclical capital requirements

In this section we conduct a counterfactual analysis by comparing the dynamics of the model with the CcCR rule C and with a constant capital requirement. For brevity, we present only the results for the optimal rule C, which reacts to changes in credit and output.<sup>25</sup> To keep this consistent with the previous analysis, we consider the same shocks: a positive housing demand shock and a negative loan repayment shock. The results from both shocks show that the rule-based CcCR significantly attenuates the effect of the shock. This implies that the optimal

<sup>25</sup>Rule C is the most effective policy rule based on our previous analysis. The results with other policy rules (rules A, B and D) are available upon request.

rule-based CcCR is more effective in enhancing financial and macroeconomic stability than a constant capital requirement.

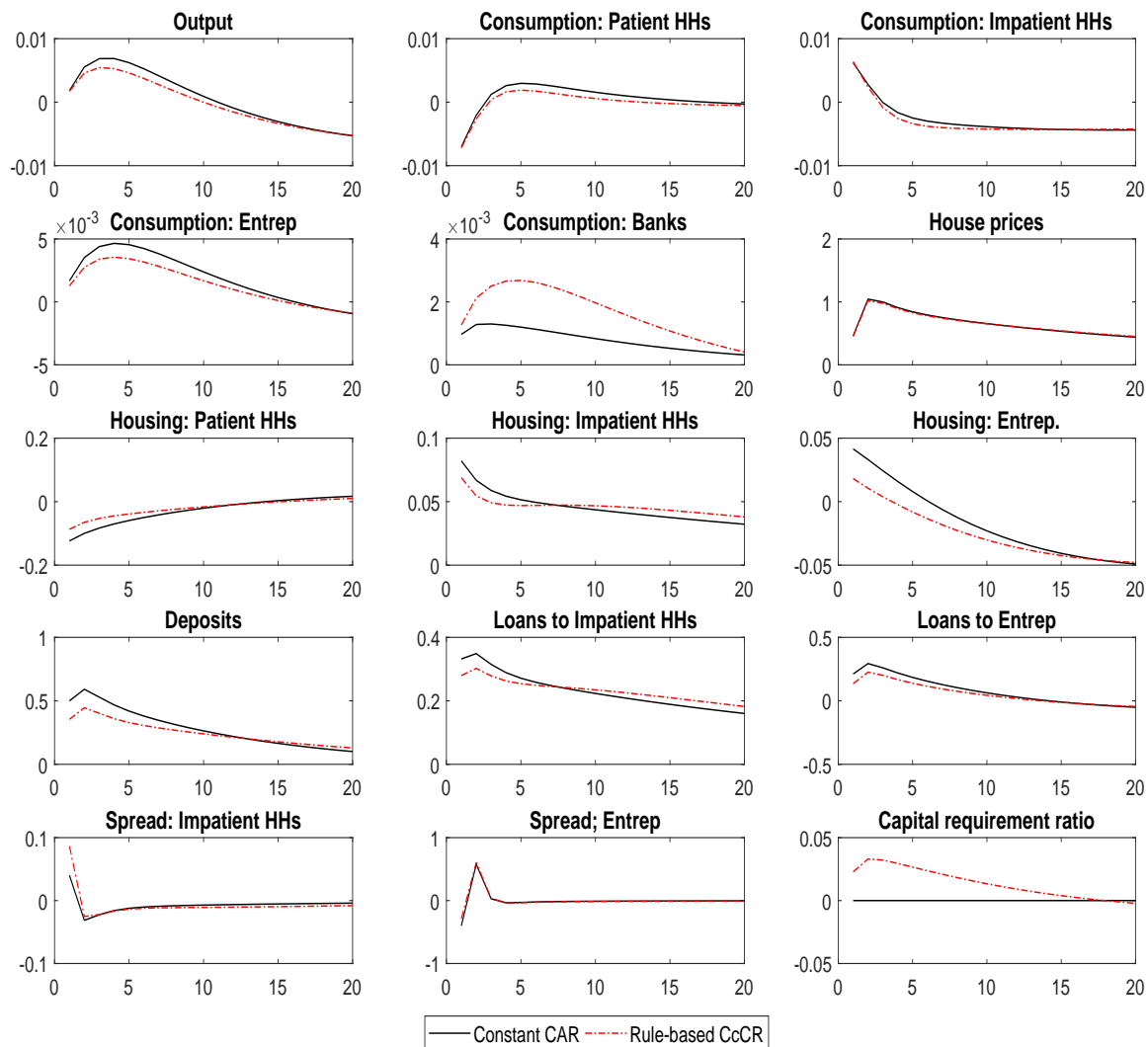


Figure 2.9: Impulse responses to a positive housing demand shock under the optimal countercyclical capital requirement rule C (red dash dot lines) and the counter-factual regime where there is no macroprudential policy (black solid lines). *Note:* Variables are expressed in % deviations from steady states, interest rates are in percentage points. HHs and Entrep stand for households and entrepreneur.

Fig. 2.9 presents the impulse responses of the key variables to a positive housing demand shock under a constant capital requirement ratio (black solid lines) and the optimal CcCR rule C (red dash dot lines). Under CcCR rule C, the increase in credit and output causes the countercyclical capital buffer to tighten credit conditions in an economic boom. This moderates borrowers' demand for housing and attenuates the impact of the shock on the real economy. From a policy perspective, these findings support the notion that cyclically adjusted capital re-

quirements can contain the build-up of systemic risk and foster financial stability by preventing credit and housing market bubbles.

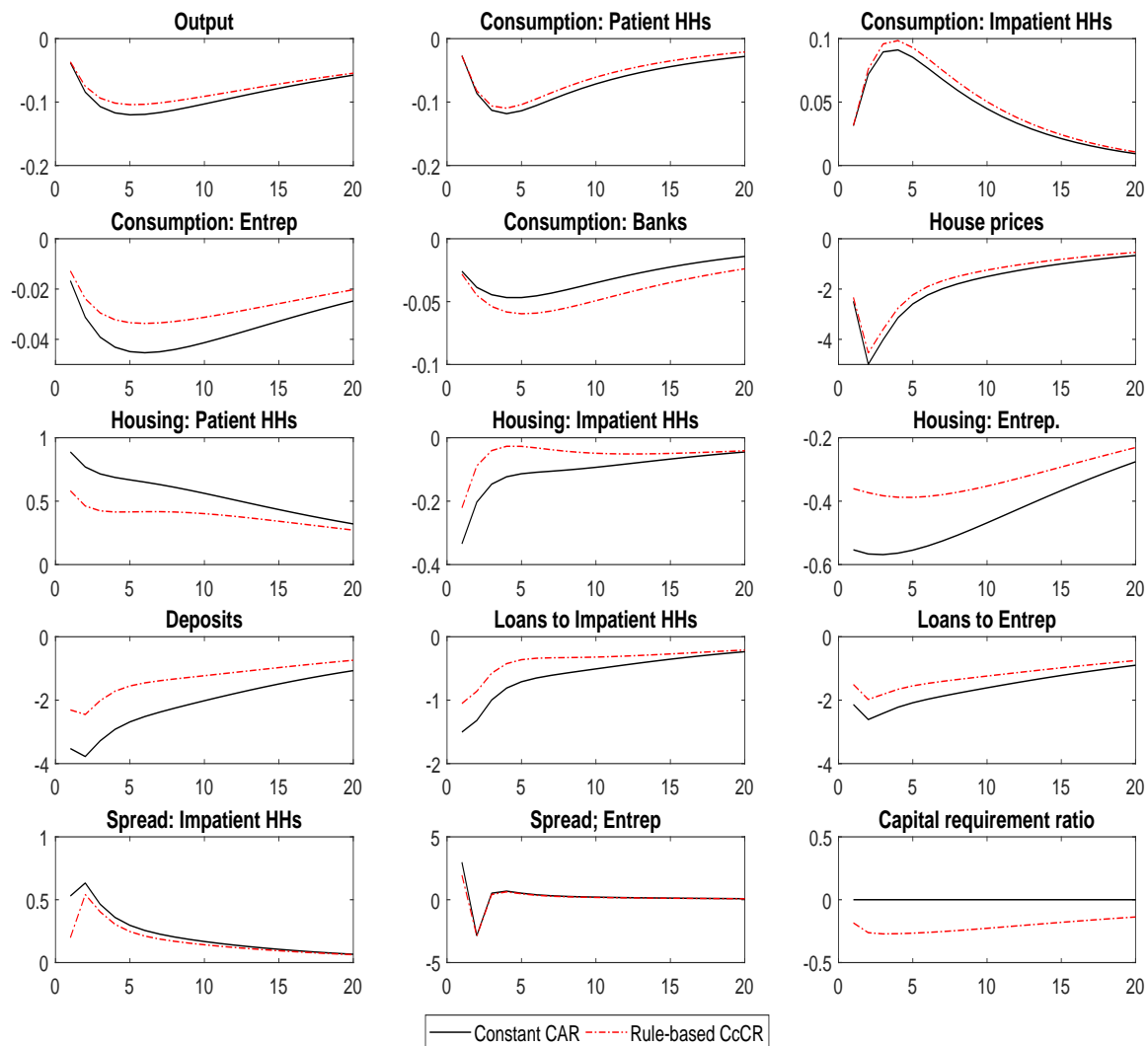


Figure 2.10: Impulse responses to a negative loan repayment shock (impatient household) under the optimal countercyclical capital requirement rule C (red dash dot lines) and the counter-factual regime where there is no macroprudential policy (black solid lines). *Note:* Variables are expressed in % deviations from steady states, interest rates are in percentage points. HHs and Entrep stand for households and entrepreneur.

Fig. 2.10 presents the results with a negative financial shock. Under the optimal CcCR rule C, capital requirement ratio declines when credit and output fall. The relaxation of the regulatory requirement enables banks to absorb loan losses without needing to adjust their balance sheet drastically or increase interest rates substantially. Consequently, the magnitude of the credit and housing market bust is smaller than that under the constant capital requirement regime. The decline in aggregate consumption and output also becomes smaller. This im-

plies that CcCRs can reduce a systemic credit crunch and lessen the severity of a recession by relaxing the regulatory requirements.

## 2.8 Conclusion

The paper presents a real business cycle DSGE model with a stylised banking sector and macroprudential authority, and studies the effectiveness of the rule-based Basel III CcCRs in attenuating fluctuations in credit and housing markets and mitigating pro-cyclicality of Basel II in the context of South Africa. We decompose the transition from Basel II to Basel III capital requirements into two stages, namely the permanent increase of capital requirement ratio by 2.5% in line with the capital conservation buffer, and the introduction of the countercyclical capital buffer. We find that the rule-based Basel III CcCRs are effective in attenuating credit and housing markets boom-bust cycles and mitigating the pro-cyclicality of the Basel II capital regulation, while the impact of the conservation capital buffer is negligible. Taken together, these findings support the view that the new bank capital regulation can prevent potential credit and housing market bubbles and contain the build-up of systemic risk in a boom period. In economic downswing, the regulation mitigates the problem of credit squeeze and helps avoid severe recession.

We also compare the effectiveness of four alternative CcCR rules and establish that the one reacting to changes in credit and output improves the ability of the macroprudential authority to deliver on financial and macroeconomic stability mandates. The optimal implementation of this rule requires an aggressive response to output and a moderate response to credit. The second best rule is the one in which the CcCR responds to credit, house prices and output while those responding to credit only and credit-to-output only are ranked third and fourth, respectively.

## Chapter 3

# The effectiveness of the countercyclical loan-to-value regulation: generic versus sector-specific rules<sup>1</sup>

### 3.1 Introduction

Policy makers and academics have been emphasising the role of macroprudential policy in strengthening the resilience of the financial system and fostering financial stability since the 2007/08 global financial crisis. One of the key issues is the design of the macroprudential policy. This includes measures to reduce the systemic risk that arises from excessive fluctuations in credit supply and the pro-cyclical nature of the financial sector (Claessens et al., 2013). One of these measures is the countercyclical loan-to-value (CcLTV) regulation. The intuition behind the CcLTV regulation is to adjust the LTV ratio in a countercyclical manner to lean against credit and house-price cycles. During an economic boom, the LTV ratio is tightened in order to dampen the excessive credit growth and prevent bubbles, such as a house price bubble. In this way, the regulation can contain the build-up of systemic risk and promote financial stability. When systemic risk materialises, the LTV ratio is relaxed, to prevent a sharp decline in the demand for credit, house price collapse and rapid deleverage in the banking sector. This relaxation mitigates the spillover of financial vulnerabilities to the real sector.

While there is consensus that financial regulation is moving towards the macroprudential

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<sup>1</sup>This chapter is published as a working paper of Economic Research Southern Africa (ERSA). See Liu and Molise (2019a).



approach with well-defined policy toolkits, the design and the implementation of the policy tools remain a challenge. Most studies in the literature examine a unique CcLTV regulation in a model economy regardless of the type of borrower - either household or non-financial corporate or both.<sup>2</sup> Very few studies examine a borrower-specific CcLTV regulation in a model where borrowers of more than one type from distinct sectors of the credit market co-exist. An exception is the paper by Punzi and Rabitsch (2018), which examines a general equilibrium model with low- and high-leveraged household borrowers and considers the effectiveness of CcLTV regulations that target the two types of household borrowers. This study, however, lacks a rigorous analysis of the CcLTV regulation in this model. It is thus not informative for policymakers looking for the optimal design for the CcLTV regulation in an environment where there are several types of borrowers from distinct sectors of the credit market.

As cyclical patterns of household credit and non-financial corporate credit differ, macroprudential tools should be designed and implemented to suit the different patterns. Fig. 3.1 shows how household and corporate credit behaved differently over the sample period 1994Q1 to 2016Q4 in South Africa. Household credit experienced a sustained growth from 2002 to 2008, associated with the South Africa's housing market boom. Before this steep climb, household credit had been decreasing since 1998, and it decreased again after the financial crisis. In contrast, corporate credit had been flat since 1998 and only started catching up with household credit from 2005. It is also worth noting that corporate credit started recovering again from 2013, whereas household credit continued to decline after the crisis. The figure also shows that the credit-to-GDP ratio for corporate credit is, on average, above 30% over the sample period, which is approximately 10% higher than that of household credit.

This paper contributes to the literature on macroprudential policy by investigating the implications of the CcLTV regulation where heterogeneous borrowers from distinct sectors of the credit market co-exist. Our aim is to identify the optimal design. This is in contrast to studies that consider a single CcLTV regulation in a setting where there is only one type of borrower, or where there are homogeneous borrowers from one sector of the credit market. We argue that fluctuations in different types of credit affect the real economy through different channels. For

<sup>2</sup>A non-exhaustive list includes Lambertini et al. (2013), Angelini et al. (2014), Quint and Rabanal (2014), Rubio and Carrasco-Gallego (2014), Mendicino and Punzi (2014), Brzoza-Brzezina et al. (2015), Ravn (2016), Rubio and Yao (2017) and Garbers and Liu (2018). These studies find that the CcLTV regulation delivers more stable financial and macroeconomic conditions and improves social welfare. For example, Lambertini et al. (2013) establish that the CcLTV rule reacting to credit growth is effective in stabilising fluctuations in house prices and credit, and leads to Pareto optimality. Rubio and Carrasco-Gallego (2014) show that the CcLTV rule that responds to changes in credit is effective in mitigating the fluctuations in credit growth and enhances welfare.

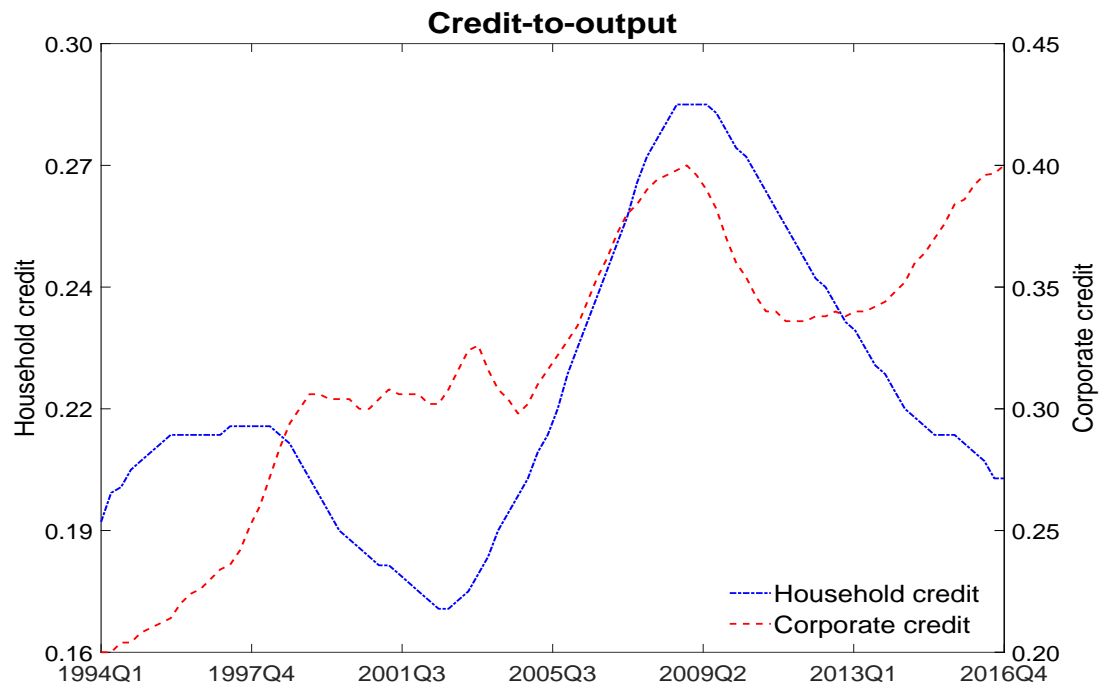


Figure 3.1: Credit-to-output ratios in South Africa.

example, changes in household credit affect the economy through the demand for consumption goods and services and for housing investment, whereas changes in corporate credit affect the economy through investment in physical capital and housing (commercial real estate) and through the demand for labour. That is, changes in household credit affect the economy mainly from the demand side, whereas changes in corporate credit affect the economy mainly from the supply side. The regulatory authority should therefore assess potential risks in specific sectors of the credit market and implement the CcLTV accordingly. This would avoid the potential costs that arise from implementing a one-size-fits-all CcLTV, which over-reacts in a sector of the market where there are no risks and under-reacts in one where there are high risks.

We propose two policy regimes for the implementation of the CcLTV regulation: one generic and one sector-specific. Under the generic regime, the authority adjusts the household and corporate LTV ratios to changes in aggregate credit and output; under the sector-specific regime, the authority adjusts those ratios according to their specific sectoral credit conditions and output, with different intensities.<sup>3</sup> We then compare the effectiveness of the two policy regimes in enhancing financial and macroeconomic stability. To measure financial stability we use the volatility of credit and house prices, and to measure macroeconomic stability we use the volatility of output, along the lines of Rubio and Carrasco-Gallego (2014) and Agénor and

<sup>3</sup>By different intensities we mean that the policy coefficients on output in the household CcLTV rule and the corporate CcLTV rule are different.

Pereira da Silva (2017). We pose the question whether the authority should use the generic CcLTV regime or the sector-specific CcLTV regime when implementing the CcLTV regulation in a setting where there are two types of borrowers: households, which borrow to finance consumption, and entrepreneurs, who borrow to finance production.

To do so, we develop a real business cycle dynamic stochastic general equilibrium (DSGE) model that incorporates the role of macroprudential policy. Our model abstracts from nominal rigidities because in this paper we focus on the role of the CcLTV regulation in fostering financial and macroeconomic stability. The model is based on the framework of Iacoviello (2015), and populated by patient households (savers), banks, a macroprudential authority and two types of borrower - household (impatient households) and corporate (entrepreneurs). The two types of borrower face borrowing constraints which state that the amount borrowed cannot exceed a certain fraction of the value of their collateral assets. The macroprudential authority adjusts its policy instrument, the loan-to-value ratio, in a countercyclical manner to foster financial and macroeconomic stability. The model is calibrated using South African data. It reproduces the cyclical moments of both the financial and real sectors fairly well. Given its simplicity and the small number of shocks considered, the model performs fairly satisfactorily in matching what we observe in the data.

Our key findings are as follows. We first derive the optimal rules for generic and sector-specific regimes and compare their effectiveness in minimising the macroprudential authority's loss function (welfare loss). We find that the sector-specific regime is more effective than the generic regime in minimising welfare loss, particularly when the economy is hit by technology and financial shocks. However, when a housing demand shock hits the economy the generic regime is more effective in minimising welfare loss. For both regimes, therefore, optimal policy rules depend on the kind of shock. Both the corporate and the household CcLTV regimes require an aggressive reaction to credit following financial and housing demand shocks and only a moderate reaction to credit following a technology shock. Under the sector-specific regime, the policy requires a stronger response to credit and output for the corporate CcLTV rule than for the household CcLTV rule. Compared to the baseline case (with constant LTV), both the generic and the sector-specific regimes are effective in minimising the volatility of the three key policy variables (credit, house prices and output), especially for credit. The sector-specific regime provides a higher degree of macroeconomic stability than the generic regime. This stabilisation effect becomes more significant when the economy faces financial and housing

demand shocks.

The results of an impulse response analysis suggest that both the generic and the sector-specific regimes are effective in achieving the two objectives of macroprudential policy: financial and macroeconomic stability. This is achieved mainly by attenuating the amplification effects of the borrowing constraint channel. The effectiveness of both regimes is, however, shock dependent. When the economy faces a technology shock, their effectiveness is more or less the same. When the economy faces a financial shock, the sector-specific regime significantly outperforms the generic regime in attenuating the business cycle fluctuations, whereas the opposite is true when the economy is hit by a housing demand shock. When one sector of the credit market is hit by a financial shock, while the other sector is unaffected, the sector-specific regime plays an important role in stabilising fluctuations in the two credit market sectors and hence reducing the fluctuations in output. This implies that by adopting the sector-specific regime the macroprudential authority can avoid the potential costs arising from implementing the generic regime and achieve both financial and macroeconomic stability in a more effective way. On the other hand, when both sectors of the credit market are hit by the same shock (the housing demand shock), the generic regime outperforms the sector-specific regime in achieving financial and macroeconomic stability. Since the CcLTV regulation works through the borrowing constraint channel and housing is used as a collateral asset for both types of borrowers, the shock affects both types of borrower in the same way. In this case the macroprudential authority can implement the generic regime and not only achieve its two policy objectives but also minimise the welfare loss.

Importantly, these results indicate that when uncertainty occurs in the credit market, the macroprudential authority should first identify the source of the uncertainty. If the shock hits one sector of the credit market only, implementing the generic CcLTV regime can lead to an over-reaction in the other credit market sector and under-reaction in the sector that is hit by the shock. Instead of correcting financial imbalances in the shock-affected credit market sector, the generic regime exacerbates the effect of the shock on this shock-affected sector. We argue that this potential drawback of over-reaction in one sector of the credit market and under-reaction in the other can be eliminated by implementing the sector-specific regime. The regulator's flexibility in customising the CcLTV regulation according to the specific conditions of each credit market sector will enable the regulator to eliminate the imbalances in both sectors.

The efficient policy frontiers under the two policy regimes present a clear trade-off between

financial and macroeconomic stability, as the authority adjusts its preference between the two policy objectives. Our results show that the sector-specific CcLTV regime is more effective than the generic CcLTV regime in stabilising the volatility of credit and output and can deliver a larger reduction in output volatility at a lower cost of financial instability.

In terms of the implementation of the two CcLTV regimes, we find that the proposed CcLTV regimes have the potential to deliver on financial and macroeconomic stability mandates. However, this stabilising effect on financial stability diminishes if the regulator responds aggressively to changes in credit. Responses to changes in output can achieve financial stability only if the regulator responds moderately to changes in financial variables. However, regardless of whether the regulatory authority responds to changes in output aggressively or not, an aggressive response to changes in credit does not contribute to macroeconomic stability, whereas a moderate response to changes in credit has a significant impact.

The rest of the paper is organised as follows. Section 3.2 describes the model and Section 3.3 presents the calibration of the model. Section 3.4 describes the model's business cycle properties. Section 3.5 presents the optimal simple rules for implementing the generic and sector-specific CcLTV regimes and compares their effectiveness in minimising the loss function of the macroprudential authority. Section 3.6 presents the impulse response functions analysis, Section 3.7 explains the efficient policy frontier for the two CcLTV regimes, Section 3.8 describes the implementation of the optimal CcLTV and Section 3.9 concludes.

## 3.2 The model

Our model is a closed economy real business cycle model, featuring a banking sector, a housing market and the macroprudential authority. Specifically, the model is built on the workhorse of Iacoviello (2015) and incorporates the role of the macroprudential authority in implementing the CcLTV regulation to foster financial and macroeconomic stability. Since our focus is on the optimal design and the effectiveness of macroprudential policy, our model abstracts from nominal rigidities.

The model features two types of households (patient and impatient), entrepreneurs, the bank and the macroprudential authority. Households work (i.e. supply labour), and consume the final output (consumption goods) and housing. Patient households are the savers in the economy and provide the bank with savings deposits. Impatient households are one type of borrower in the

economy, using their housing as a collateral asset to secure credit from the bank. Entrepreneurs are the other type of borrower in the economy, producing the final output using household labour and housing as inputs. To finance their production, entrepreneurs borrow funds from the bank against their stock of housing. The bank mediates funds between savers (patient households) and borrowers (impatient households and entrepreneurs). The macroprudential authority is responsible for financial stability using the CcLTV regulation. While there is no consensus in the literature on which variables to include in the macroprudential policy rules, we assume that the authority adjusts the LTV ratios to changes in credit and output. This kind of policy rule is consistent with the main objective of macroprudential policy: to protect the financial system from the risks associated with excessive credit growth without compromising macroeconomic stability. For the purpose of our study, we consider two CcLTV regimes, generic and sector-specific.

### 3.2.1 Patient Households (Savers)

The representative patient household chooses real consumption ( $C_{s,t}$ ), housing ( $H_{s,t}$ ) and leisure ( $1 - N_{s,t}$ ) to maximise the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left[ (1 - \eta_s) \log(C_{s,t} - \eta_s C_{s,t-1}) + j A_t \log(H_{s,t}) + \tau \log(1 - N_{s,t}) \right], \quad (3.1)$$

where  $E_0$  and  $\beta_s \in (0, 1)$  are the expectation operator and the household's subjective discount factor, respectively. Consumption appears in the utility function relative to external habit formation, with  $\eta_s$  measuring degree of habit persistence. In line with Iacoviello (2015) and Guerrieri and Iacoviello (2017), the scaling factor  $1 - \eta_s$  ensures that the marginal utility of consumption is independent of the habit parameter in the steady state.  $j$  and  $\tau$  are weights of housing and leisure in the utility function, respectively.  $A_t$  is the housing demand shock, which evolves according to the following law of motion:

$$\log(A_t) = \rho_a \log(A_{t-1}) + \xi_{a,t}, \quad (3.2)$$

where  $\rho_a$  is a parameter representing the persistence of the shock.  $\xi_{a,t} \sim i.i.d.N(0, \sigma_a^2)$  is white noise process, normally distributed with mean zero and variance  $\sigma_a^2$ . The housing demand shock captures exogenous factors that shift the household's preference and demand for housing. Iacoviello (2005) suggests that the housing demand shock offers a parsimonious way to analyse exogenous disturbances to house prices.

In each period, the household begins with housing stock ( $H_{s,t-1}$ ) and savings deposits ( $D_{t-1}$ ) coming to mature. The household supplies labour to entrepreneurs and receives real wage rate  $W_{s,t}$ .  $R_{d,t}$  is the real gross return on a one-period risk-free deposit and  $q_t$  is the relative price of housing (in units of consumption). The household's budget constraint is given by:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_{s,t}N_{s,t} + R_{d,t-1}D_{t-1}. \quad (3.3)$$

Let  $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t}-\eta_s C_{s,t-1}}$  be the marginal utility of consumption. The first order conditions for the household's problem are as follows:

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \quad (3.4)$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \quad (3.5)$$

$$W_{s,t} = \frac{\tau}{(1 - N_{s,t}) U_{Cs,t}}. \quad (3.6)$$

Eq. (3.4) is the standard consumption Euler equation. Asset pricing Eq. (3.5) for housing equates the marginal cost of housing to its marginal benefit. For the household the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of housing in units of consumption plus the present discounted value of housing. Eq. (3.5) can also be regarded as household's demand for housing. The household's labour supply condition Eq. (3.6) equates the real wage rate to the marginal rate of substitution between consumption and leisure.

### 3.2.2 Impatient Households (Borrowers)

Like the patient household, the representative impatient household maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[ (1 - \eta_b) \log(C_{b,t} - \eta_b C_{b,t-1}) + j A_t \log(H_{b,t}) + \tau \log(1 - N_{b,t}) \right], \quad (3.7)$$

where  $\beta_b$  is the household's subjective discount factor and  $\beta_b < \beta_s$ .  $C_{b,t}$  is the household's real consumption,  $H_{b,t}$  is its housing stock and  $N_{b,t}$  is its labour supply. Its budget constraint is given by:

$$C_{b,t} + R_{b,t-1}L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) = W_{b,t}N_{b,t} + L_{b,t} + \zeta_{b,t}, \quad (3.8)$$

where  $L_{b,t}$  is the bank's loan to the household which accrues a real gross interest rate of  $R_{b,t}$ .  $W_{b,t}$  is real wage rate for the household. Following Iacoviello (2015), we introduce an exogenous loan loss shock  $\zeta_{b,t}$ .<sup>4</sup> Intuitively, this shock can be thought of as a partial default by the household on its loan. For the household, a loan default is an indirect increase in wealth. By paying less than the contracted amount, the household can spend more than it anticipated. The same shock appears with a negative sign in the bank's budget constraint. The shock evolves according to the following law of motion:

$$\zeta_{b,t} = \rho_\zeta \zeta_{b,t-1} + \xi_{\zeta,t}, \quad (3.9)$$

where  $\rho_\zeta$  is the parameter representing the persistence of the shock.  $\xi_{\zeta,t} \sim i.i.d.N(0, \sigma_\zeta^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_\zeta^2$ .

The household faces a credit constraint that limits the amount borrowed to a fraction  $m_{b,t}$  of the expected value the housing:

$$L_{b,t} \leq m_{b,t} E_t \left( \frac{q_{t+1}}{R_{b,t}} H_{b,t} \right). \quad (3.10)$$

$m_{b,t} \in (0, 1)$  is the loan-to-value (LTV) ratio for the impatient household. The LTV ratio is determined by the macroprudential authority as its regulatory instrument.

Let  $U_{Cb,t} = \frac{1-\eta_b}{C_{b,t}-\eta_b C_{b,t-1}}$  be the marginal utility of consumption and  $\lambda_{b,t}$  be the multiplier on the borrowing constraint. The first order conditions which define the household's problem are:

$$1 = \beta_b E_t \frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t} + \frac{\lambda_{b,t}}{U_{Cb,t}}, \quad (3.11)$$

$$q_t = j \frac{A_t}{H_{b,t} U_{Cb,t}} + \beta_b E_t \left( \frac{U_{Cb,t+1}}{U_{Cb,t}} \right) q_{t+1} + m_{b,t} (\lambda_{b,t} / U_{Cb,t}) E_t \frac{q_{t+1}}{R_{b,t}}, \quad (3.12)$$

$$W_{b,t} = \frac{\tau}{(1 - N_{b,t}) U_{Cb,t}}. \quad (3.13)$$

Eq. (3.11) represents the household's demand for a bank loan. It differs from the standard Euler equation because of the borrowing constraint. Asset pricing Eq. (3.12) for housing equates the marginal cost of housing to its marginal benefit. For the household, the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of housing service in units of consumption (the marginal rate of substitution between housing and consumption) plus the present discounted value of housing (the benefit the housing provides in the

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<sup>4</sup>Loan losses are scaled by steady-state value of bank loans to impatient households analogous to Iacoviello (2015).



next period as a store of wealth). Eq. (3.12) is the household's demand for housing. Eq. (3.13) is the household's labour supply condition.

### 3.2.3 Entrepreneurs

Entrepreneurs produce final output ( $Y_t$ ) using two types of household labour supply ( $N_{s,t}$  and  $N_{b,t}$ ) and housing ( $H_{e,t}$ ) as inputs. The representative entrepreneur maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1 - \eta_e) \log(C_{e,t} - \eta_e C_{e,t-1}), \quad (3.14)$$

where  $\beta_e < \beta_s$ .  $C_{e,t}$  is the entrepreneur's real consumption, which can be regarded as profits or dividends. Therefore,  $\eta_e C_{e,t-1}$  captures some form of dividend smoothing in line with Liu et al. (2013). Liu et al. (2013) note that this form of dividend smoothing is essential to adequately explain the dynamics between asset prices and real variables. The budget constraint for the entrepreneur is given by:

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_{s,t}N_{s,t} + W_{b,t}N_{b,t} = Y_t + L_{e,t} + \zeta_{e,t}, \quad (3.15)$$

where  $N_{s,t}$  and  $N_{b,t}$  are patient and impatient households' labour supply, respectively.  $L_{e,t}$  is the amount borrowed from the bank, which accrues a real gross interest rate of  $R_{e,t}$ . The term  $\zeta_{e,t}$  captures an exogenous loan repayment shock.<sup>5</sup> Like the impatient household's loan loss shock, the shock represents an indirect increase in wealth in the event of default. The shock evolves according to the following law of motion:

$$\zeta_{e,t} = \rho_{\zeta} \zeta_{e,t-1} + \xi_{\zeta,t}, \quad (3.16)$$

where  $\rho_{\zeta}$  is the persistence of the shock.  $\xi_{\zeta,t} \sim i.i.d.N(0, \sigma_{\zeta}^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_{\zeta}^2$ .

Production technology is given by a constant return to scale Cobb-Douglas production function:

$$Y_t = Z_t H_{e,t}^{\nu} [N_{s,t}^{1-\sigma} N_{b,t}^{\sigma}]^{1-\nu}, \quad (3.17)$$

where the parameter  $\nu \in (0, 1)$  is the elasticity of output with respect to housing and  $\sigma \in (0, 1)$  measures the impatient households' labour output share.<sup>6</sup> Technology shock ( $Z_t$ ) evolves

<sup>5</sup>Entrepreneur loan losses are scaled by steady-state value of bank loans to entrepreneurs analogous to Iacoviello (2015).

<sup>6</sup>As in Iacoviello (2015), the production technology assumes that the two types of labour (patient and impatient households) are complements. This assumption ensures that we obtain a close-form solution for the steady state of the model (Mendicino and Punzi, 2014).

according to the following law of motion:

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}, \quad (3.18)$$

where  $\rho_z$  is the parameter representing the persistence of the shock.  $\xi_{z,t} \sim i.i.d.N(0, \sigma_z^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_z^2$ .

The entrepreneur also faces the borrowing constraint:

$$L_{e,t} \leq m_{e,t} E_t \left( \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right). \quad (3.19)$$

Eq. (3.19) suggests that the total amount of credit the entrepreneur can secure from the bank cannot exceed a fraction  $m_{e,t}$  of the expected market value of the entrepreneur's collateral assets.  $m_{e,t} \in (0, 1)$  represents the LTV ratio for the entrepreneur (the corporate LTV ratio) and is determined by the macroprudential authority as its regulatory instrument.<sup>7</sup> The dual role of housing as collateral asset and productive input is widely acknowledged in the DSGE literature (see for e.g., Iacoviello, 2005; Chaney et al., 2012; Liu et al., 2013; Minetti and Peng, 2013).<sup>8</sup> As we show later, the condition  $\beta_e < \beta_s$  ensures that the borrowing constraint Eq. (3.19) is binding in the neighbourhood of the steady-state.

Let  $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$  be the marginal utility of consumption and  $\lambda_{e,t}$  be the multiplier on the borrowing constraint Eq. (3.19). The first order conditions which define the entrepreneur's problem are as follows:

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \nu \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) + m_{e,t} (\lambda_{e,t} / U_{Ce,t}) E_t \frac{q_{t+1}}{R_{e,t+1}}, \quad (3.20)$$

$$W_{s,t} N_{s,t} = (1 - \sigma)(1 - \nu) Y_t, \quad (3.21)$$

$$W_{b,t} N_{b,t} = \sigma(1 - \nu) Y_t, \quad (3.22)$$

$$1 = \lambda_{e,t} / U_{Ce,t} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}. \quad (3.23)$$

Eq. (3.20) represents the entrepreneur's demand for housing. It equates the marginal cost of one extra unit of housing (price of housing) to its marginal benefits. For the entrepreneur,

<sup>7</sup>Throughout the paper, corporate LTV ratio means LTV ratio for entrepreneurs.

<sup>8</sup>Using housing stock as one production input provides a motive for entrepreneurs to hold housing stock, which is in turn being used as a collateral asset for securing bank credit. This also allows us to analyse the impact of house prices (one of our measures of financial stability) on the entrepreneur's investment and production decisions.

the marginal benefits of housing are given by the present discounted value of the next period's real return on housing plus the benefit of housing as a collateral asset for securing credit. The entrepreneur's real return on housing is given by the marginal product of the housing and the future resale value of the housing. In essence, condition Eq. (3.20) equates the current price of housing to its expected resale value plus the pay-off from holding this asset for one period (given by the marginal productivity of housing and its ability to serve as collateral). Eqs. (3.21) and (3.22) are labour demand conditions. Eq. (3.23) is the asset pricing equation for the entrepreneur's demand for credit.

### 3.2.4 The bank

The bank is a financial intermediary that mediates funds between savers (patient households) and borrowers (impatient households and entrepreneurs). The representative bank chooses real consumption ( $C_{f,t}$ ) to maximise the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1 - \eta_f) \log(C_{f,t} - \eta_f C_{f,t-1}), \quad (3.24)$$

where  $\beta_f$  is the bank's subjective discount factor. Note that  $C_{f,t}$  can be interpreted as dividend payments from the bank, which are assumed to be fully consumed by the bank.  $\eta_f C_{f,t-1}$  represents some form of dividend smoothing. The bank's budget constraint is given by:

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1} L_{b,t-1} + R_{e,t} L_{e,t-1} - \zeta_t, \quad (3.25)$$

where  $D_t$  is the household's deposits.  $L_{b,t}$  and  $L_{e,t}$  are bank lending to impatient households and entrepreneurs, respectively.  $AC_{bf,t} = \frac{\phi_{bf}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_b}$  and  $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$  are quadratic loan portfolio adjustment costs associated with household and entrepreneur loans, respectively.  $\zeta_t = \zeta_{b,t} + \zeta_{e,t}$  is the loan repayment shock. This represents loan losses that the bank incurs when impatient households and entrepreneurs default on their loans. From the bank's perspective, loan losses also represent a shock to their net worth. An increase in loan losses reduces the bank's profits and impairs its balance sheet. This results in a decline in the bank's capital.

The bank is also subject to capital requirement in line with the Basel capital regulations. Specifically, the bank is required to hold a certain amount of bank capital that covers, at least, a specified fraction of its assets (loans). Let  $BK_t = L_t - E_t \zeta_{t+1} - D_t$  be the bank's capital. The

capital requirement constraint is given by<sup>9</sup>:

$$\frac{L_t - E_t \zeta_{t+1} - D_t}{w_b(L_{b,t} - E_t \zeta_{b,t+1}) + w_e(L_{e,t} - E_t \zeta_{e,t+1})} \geq \kappa, \quad (3.26)$$

where  $\kappa \in (0, 1)$  is capital requirement ratio and  $L_t = L_{b,t} + L_{e,t}$  is the aggregate credit.  $E_t \zeta_{t+1}$  represents allowance for expected loan losses.  $w_b$  and  $w_e$  denote risk weights on household and entrepreneur borrowing, respectively. These parameters capture different degrees of risk associated with household and entrepreneur borrowing. The capital requirement constraint (3.26) can be rewritten as a borrowing constraint as follows:

$$D_t \leq (1 - w_e \kappa)(L_{e,t} - E_t \zeta_{e,t+1}) + (1 - w_b \kappa)(L_{b,t} - E_t \zeta_{b,t+1}). \quad (3.27)$$

Eq. (3.27) states that the amount that the bank can take as a deposit from households cannot exceed a weighted sum of the bank's assets net of the expected loan losses, where the weights on the two classes of the bank's assets are given by  $(1 - w_i \kappa)$ , for all  $i = \{b, e\}$ . The capital requirement constraint limits the extent to which the bank can take on leverage. The assumption is that the bank is more impatient than the patient household; that is  $\beta_f < \beta_s$ , ensures that the borrowing constraint (3.27) is binding in the steady state. In the absence of this assumption, the bank may find that it is optimal to postpone current consumption indefinitely and accumulate capital to the point where the capital requirement constraint does not have force.

Let  $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t}-\eta_f C_{f,t-1}}$  be the marginal utility of consumption and  $\lambda_{f,t}$  be the multiplier on the bank's borrowing constraint (3.27). The bank's optimal condition for deposits and credit to households and entrepreneurs are given by:

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t} = 1 - \lambda_{f,t} / U_{Cf,t}, \quad (3.28)$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t} = 1 - (1 - w_b \kappa)(\lambda_{f,t} / U_{Cf,t}) + \frac{\phi_{bf}}{L_b}(L_{b,t} - L_{b,t-1}), \quad (3.29)$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (1 - w_e \kappa)(\lambda_{f,t} / U_{Cf,t}) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}). \quad (3.30)$$

The banks' demand for deposits (3.28) equates the current pay-off from taking one extra unit of deposit from the patient household to the discounted cost of raising such deposits.

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<sup>9</sup>For simplicity, the paper does not distinguish between required capital and excess capital held voluntarily by South African banks. South African banks consistently maintain capital adequacy ratios over the regulatory requirements. Over the period 2008 - 2015, the average amount of excess bank capital held by SA banks is estimated at 4% of risk weighted assets (Liu and Seeiso, 2012)

Eqs. (3.29) and (3.30) equate the present discounted pay-off of providing one extra unit of credit (to impatient households and entrepreneurs) to the cost of providing such credit.

From Eqs. (3.28) to (3.30), the evolution of interest rate spreads are given by:

$$R_{b,t} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[ w_b \kappa (\lambda_{f,t} / U_{Cf,t}) + \frac{\phi_{bf}}{L_b} (L_{b,t} - L_{b,t-1}) \right], \quad (3.31)$$

$$R_{e,t+1} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[ w_e \kappa (\lambda_{f,t} / U_{Cf,t}) + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}) \right]. \quad (3.32)$$

In the steady state, Eqs. (3.4) and (3.28) suggest that the bank's borrowing constraint (3.27) (and hence capital requirement constraint) holds with equality as long as  $\beta_f < \beta_s$ . Formally:

$$\lambda_f C_f = \frac{\beta_s - \beta_f}{\beta_s} > 0, \quad (3.33)$$

so long as,

$$\beta_f < \beta_s. \quad (3.34)$$

Furthermore, if conditions (3.33) and (3.34) hold there will be a positive spread between the lending rate and deposit rate. That is, from Eqs. (3.31) to (3.34), it follows that:

$$R_b - R_d = \frac{w_b \kappa (\beta_s - \beta_f)}{\beta_s \beta_f} > 0, \quad (3.35)$$

$$R_e - R_d = \frac{w_e \kappa (\beta_s - \beta_f)}{\beta_s \beta_f} > 0. \quad (3.36)$$

Given the lending rate  $R_b$ , Eq. (3.11) suggests that the necessary condition for impatient household's borrowing constraint (3.10) to hold with equality (that is,  $(\lambda_b C_b) > 0$ ) is:

$$\frac{1}{\beta_b} > R_b. \quad (3.37)$$

Alternatively, using Eqs. (3.29) and (3.33), the condition for impatient household's borrowing constraint to hold with equality requires that:

$$\frac{1}{\beta_b} > \frac{w_b \kappa}{\beta_f} + \frac{(1 - w_b \kappa)}{\beta_s}. \quad (3.38)$$

Similarly, from Eq. (3.23), it requires that:

$$\frac{1}{\beta_e} > R_e, \quad (3.39)$$

or, from equations Eqs. (3.30) and (3.33) it follows that:

$$\frac{1}{\beta_e} > \frac{w_e \kappa}{\beta_f} + \frac{(1 - w_e \kappa)}{\beta_s}, \quad (3.40)$$

for an entrepreneur's borrowing constraint (3.19) to hold with equality.

### 3.2.5 Macroprudential policies

The authority uses the countercyclical loan-to-value (CcLTV) regulation as its macroprudential tool. Adjusting the LTV ratio to changes in credit and output in a countercyclical manner captures the main objective of the macroprudential policy: to protect the financial system from the risks associated with excessive credit growth, which can have undesirable consequences for the real economy. The literature proposes several ways to implement the CcLTV. One frequently cited rule is the Taylor-type rule that says the policy instrument, the loan-to-value (LTV) ratio, should respond to variables such as credit-to-GDP ratio, credit, output, house prices or some combination of these variables (e.g., Rubio and Carrasco-Gallego, 2014). There is, however, no consensus on which variables to include in the policy rule.

We consider generic and sector-specific CcLTV policy regimes. Under the generic regime, the authority does not differentiate between the two credit market sectors and adjusts both household and corporate LTV ratios to changes in aggregate credit and output as follows:

$$m_{i,t} = m_i \left( \frac{L_t}{L} \right)^{-\chi_{l,m}} \left( \frac{Y_t}{Y} \right)^{-\chi_{y,m}}, \quad \forall i = \{b, e\}, \quad (3.41)$$

where  $m_i$  is the steady-state value of the LTV ratio,  $L$  and  $Y$  are the steady-state values of aggregate credit and output, respectively.  $\chi_{l,m} \geq 0$  and  $\chi_{y,m} \geq 0$  measure the response of the LTV ratio to deviations of credit and output from their steady states, respectively.

Under the sector-specific regime, the authority differentiates between the two credit market sectors and adjusts the two LTV ratios to changes in sectoral credit. The LTV ratios of the two sectors respond to changes in output with different intensities:

$$m_{i,t} = m_i \left( \frac{L_{i,t}}{L_i} \right)^{-\chi_{l,m_i}} \left( \frac{Y_t}{Y} \right)^{-\chi_{y,m_i}}, \quad \forall i = \{b, e\}, \quad (3.42)$$

where  $\chi_{l,m_i} \geq 0$  and  $\chi_{y,m_i} \geq 0$  measure the responses of the LTV ratios to deviations of sectoral credit and output from their steady states, respectively.

The CcLTV regulation requires the authority to decrease the LTV ratios in an upswing of the business and credit cycle, thus tightening the borrowing constraints and restraining credit growth and leverage in the credit-dependent sector. In a downswing of the cycle, the regulation requires the authority to increase the LTV ratios, thus relaxing the borrowing constraints to encourage credit growth. In this way, the authority prevents excessive fluctuation in credit and contains the build-up of systemic risk in the financial sector and the spillover of financial vulnerabilities to the real sector.

### 3.2.6 Market clearing conditions and equilibrium

The economy's aggregate resource constraint becomes:

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_t, \quad (3.43)$$

where  $Adj_t = AC_{bf,t} + AC_{ef,t}$ .

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \quad (3.44)$$

The aggregate supply of credit is given by:

$$L_t = L_{b,t} + L_{e,t}. \quad (3.45)$$

## 3.3 Calibration

We calibrate our model to the South African economy using quarterly data over the sample period 1994Q1 to 2016Q4.<sup>10</sup> Some of the parameters are calibrated using real data to match the steady-state conditions of the model and others are borrowed from the literature.

Table 3.1 shows the calibrated parameter values for the model. The discount factor for patient households (savers) is set at  $\beta_s = 0.99$  in line with the literature. Following Iacoviello (2015) and Minetti and Peng (2013), impatient households' and entrepreneurs' discount factors are calibrated at  $\beta_b = \beta_e = 0.94$ , which ensure that the borrowing constraints for both are binding in the neighbourhood of the steady state.

The weight on leisure in the households' utility function is set at  $\tau = 2$ , in line with the literature. This value implies that households devote approximately one third of their time to work. The impatient household's labour income share is calibrated at  $\sigma = 0.31$ , broadly in line with the estimated value of 0.27 in Gupta and Sun (2018) for South African economy. Parameters governing habit persistence and loan portfolio adjustment costs are calibrated as follows. Habit persistence for all agents is set at  $\eta_i = 0.7$ , which is broadly in line with the literature. The bank's loan portfolio adjustment cost parameters are set at  $\phi_{bf} = 0.25$  and  $\phi_{ef} = 0.05$  for household loans and entrepreneur loans, respectively.

The share of housing in production is set at  $\nu = 0.1$  in the ballpark of the values widely used in the literature for emerging market economies (EMEs) (e.g., Iacoviello and Minetti, 2006).

<sup>10</sup>Data source: South African Reserve Bank.

Table 3.1: Calibrated parameters.

Parameter	Symbol	Value	Parameter	Symbol	Value
Discount factor (patient HH)	$\beta_s$	0.99	Impatient HH's income share	$\sigma$	0.31
Discount factor (impatient HH)	$\beta_b$	0.94	Labor supply parameter	$\tau$	2
Discount factor (Entrep.)	$\beta_e$	0.94	Loan to HH adj. cost, Bank	$\phi_{bf}$	0.25
Discount factor (Bank)	$\beta_f$	0.945	Loan to Entrep. adj. cost, Bank	$\phi_{ef}$	0.05
Habit persistence, $i = \{s, b, e, f\}$	$\eta_i$	0.70	Risk weight (Impatient HH's loan)	$w_b$	1
Housing preference	$j$	0.10	Risk weights (Entrep. loan)	$w_e$	1
Steady state LTV ratio, impatient HH	$m_b$	0.90	Autocorr. technology shock	$\rho_z$	0.95
Steady state LTV ratio, Entrep.	$m_e$	0.70	Autocorr. housing demand shock	$\rho_a$	0.97
Steady state capital requirement ratio	$\kappa$	0.105	Autocorr. loan loss shock, $i = \{b, e\}$	$\rho_{\zeta_i}$	0.90
Housing share in production	$\nu$	0.1			

HH - Household; Entrep. - Entrepreneur.

Housing weight in the utility functions is calibrated at  $j = 0.1$ . The choice of these values pins down steady state ratio of housing wealth to output at 3.0 (annualized), of which 2.2 is residential housing wealth and 0.8 is commercial housing wealth. These ratios are fairly in line with the South African data on housing wealth.<sup>11</sup>

The steady state leverage ratios for impatient households and entrepreneurs are based on the South Africa's credit market data over the sample period. LTV ratio for impatient households is set at  $m_b = 0.9$ . This value is fairly consistent with the minimum down-payment that South African banks require for providing home loans. For the entrepreneur, LTV is set at  $m_e = 0.7$ . These values are also well within the observed maximum LTV ratios for a first-time mortgage buyer in an EME like South Africa (see, e.g. IMF, 2011). These values imply that the steady-state ratio of household mortgage loans to total output is approximately 0.33 while the ratio of corporate credit to output is 0.54, consistent with the South African credit market data.

The bank's capital requirement ratio is set to mimic the Basel III bank capital requirements. It is calibrated at  $\kappa = 0.105$ . The risk weights assigned on household and entrepreneur loans are both set at  $w_b = w_e = 1$ . The discount factor for the bank is set at  $\beta_f = 0.95$ . This value is lower than the patient households' discount factor ( $\beta_s$ ), which satisfies condition (3.34), which is required for the capital requirement constraint to hold with equality in steady state. Together with the impatient households' and entrepreneurs' discount factors, these values also guarantee that impatient households' and entrepreneurs' borrowing constraints are binding in the steady state.<sup>12</sup> Furthermore, they imply a 200 basis points spread between the lending rate and the

<sup>11</sup>The 2016 Property Sector Charter Council's (PSCC) report suggests that the share of South Africa's housing wealth to total output is approximately 2.3, 75 percent of which is constituted of residential housing wealth while the remaining is commercial housing wealth. Source: <http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html>.

<sup>12</sup>See sub-section 2.4 for a detailed discussion on the conditions for the capital requirement constraint and



deposit rate, which is broadly in line with the SA interest rate data.

Lastly, the persistence of the shocks is calibrated as follows. The autocorrelation coefficients for technology and housing demand shocks are set at  $\rho_z = 0.95$  and  $\rho_a = 0.97$  respectively, consistent with Liu and Gupta (2007) and the estimated value in Gupta and Sun (2018). The choice of a highly persistent housing demand shock is also consistent with the DSGE literature. See for example Lambertini et al. (2013), Iacoviello (2015) and Brzoza-Brzezina et al. (2015). The persistence of the financial (loan loss) shock is set at  $\rho_{\zeta_i} = 0.90$  based on the estimates in Iacoviello (2015).

### 3.4 Business cycle properties

In this section we assess the model's ability to reproduce the facts of the South African data observed over the period 1994Q1–2016Q4.<sup>13</sup> Table 3.2 shows the standard deviations of the main variables and their correlations with output as implied by the model and as calculated from the data. Model 1 shows the second moments generated from the technology shock and Model 2 shows those generated from the technology, housing demand and financial (household and corporate loan loss) shocks to capture the housing and financial market properties of the data.<sup>14</sup>

The results show that Model 1 (technology shock only) reproduces the cyclical moments of the real sector fairly well. The volatility of the output generated from the model is in line with the data. However, the model somewhat underestimates the volatilities of household consumption and house prices. The model is able to account for the fact that house prices are more volatile than output, but marginally fails to account for the fact that household consumption is also more volatile than output. Model 1 reproduces the positive correlation of consumption and house prices with output, but overestimates these correlations. Consistent with the data, the model generates stronger co-movement between output and household consumption than

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impatient households' and entrepreneurs' borrowing constraints to hold with equality in steady state.

<sup>13</sup>Data on household and corporate lending rates are only available from 2008Q1. To back-cast the missing data for the two lending rates over the period 1994Q1–2008Q4, we first run regressions of the household and the corporate lending rates (each) on a constant and the prime lending rate for the period 2008Q1–2016Q4 and then use the resulting regression coefficients together with the actual prime lending rate data.

<sup>14</sup>In line with the literature, we assume that the standard deviation of the housing demand shock is slightly larger than that of the technology shock while that of the financial shock is slightly smaller. In particular, we experiment with the values of  $\sigma_z = 0.01$ ,  $\sigma_a = 0.035$  and  $\sigma_{\zeta_i} = 0.0025$  for all  $i = \{b, e\}$ . See for example Lambertini et al. (2013), Liu et al. (2013), Rubio and Carrasco-Gallego (2014), Brzoza-Brzezina et al. (2015), Iacoviello (2015) and Ravn (2016).

Table 3.2: Business cycle properties.

Variable	Standard deviation (%)			Correlation with output		
	Data	Model 1	Model 2	Data	Model 1	Model 2
Output	1.16	1.15	1.19	1.00	1.00	1.00
Household consumption	1.76	1.09	1.10	0.81	1.00	0.98
House prices	4.59	1.66	2.19	0.30	0.88	0.77
Household deposits	2.77	3.26	4.60	0.23	0.84	0.71
Household loans	4.08	3.28	4.55	0.51	0.84	0.68
Corporate loans	4.81	3.26	4.70	0.31	0.85	0.70
Household lending rate	0.73	1.10	1.45	-0.19	-0.19	-0.19
Corporate lending rate	0.60	0.69	0.96	-0.26	-0.09	-0.10

Note. Model 1 is simulated with a technology shock only. Model 2 is simulated with technology, financial (loan loss) and housing demand shocks. Except for the lending rates, all variables are log-transformed and de-trended using the Hodrick-Prescott (HP) filter. Source: Data are from South African Reserve Bank.

between output and house prices.

Model 1 also does a reasonably good job of matching the cyclical moments of the banking sector. It performs well in replicating the standard deviations of deposits, household and corporate loans, which are fairly in line with the data. The model is able to produce a good account of the fact that these variables are more volatile than output, whereas the lending rates are less volatile than output. Furthermore, the model replicates the pro-cyclicality of deposits and the two types of loans, and does a good job of mimicking the negative correlation between the output and the lending rates.

When we simulate the model with all three shocks (Model 2), the results are improved. The inclusion of the housing demand and financial (loan loss) shocks increases the volatility of all variables and reduces the correlation of these variables with output. Model 2 is better able to reproduce the volatility of house prices and household and corporate loans. It is able to account for the fact that corporate loans are slightly more volatile than household loans as revealed in the data. However, it slightly exaggerates the volatility of the lending rates. Given its simplicity and the small number of shocks considered, the model performs fairly satisfactorily in matching what we observed in the data.

### 3.5 Optimal CcLTV rules: generic versus sector-specific

In this section we derive the optimal rules for generic and sector-specific CcLTV regimes and compare their effectiveness in fostering financial and macroeconomic stability. Following the literature (e.g., Angelini et al., 2014), we define the macroprudential authority's loss function as follows:<sup>15</sup>

$$\mathcal{L}_{mp} = \lambda_l \sigma_l^2 + \lambda_q \sigma_q^2 + \lambda_y \sigma_y^2, \quad (3.46)$$

where  $\sigma_l^2$ ,  $\sigma_q^2$  and  $\sigma_y^2$  are the unconditional variances of credit, house prices and output, respectively. The parameters  $\lambda_l \geq 0$ ,  $\lambda_q \geq 0$  and  $\lambda_y \geq 0$  represent their weights in the loss function.

The loss function (3.46) implies that the macroprudential authority strives to achieve financial stability (measured by fluctuations in credit and house prices) without compromising macroeconomic stability (measured by fluctuations in output). To simplify our analysis, we conduct experiments with the weights of  $\lambda_l = 1$ ,  $\lambda_q = 0.05$  and  $\lambda_y = 0.5$  in the loss function. The assignment of a lower weight on house prices than on credit is consistent with the empirical evidence that fluctuations in credit are more important than asset prices in predicting financial distress (Agénor and Pereira da Silva, 2017; Agénor et al., 2018). The assigned weight on output is also smaller than that on credit, reflecting the fact that the primary objective of macroprudential policy is financial stability. We then derive the optimal policy parameters  $(\chi_{l,j}^*, \chi_{y,j}^*)$ , for all  $j = \{m_b, m_e\}$ , in Eqs. (3.41) and (3.42) that minimise Eq. (3.46) subject to the constraints given by the model.

Table 3.3 shows the optimal simple rules for both the generic and the sector-specific CcLTV regimes, the corresponding loss function values and the standard deviations of the key policy variables (credit, house prices and output). To provide more insights, we report the results for the three shocks: technology (column 2), financial (household loan loss) (column 3) and housing demand (column 4).<sup>16</sup>

The results indicate that the optimal sector-specific CcLTV regime is more effective than the optimal generic CcLTV regime in minimising the welfare loss. This is particularly so

<sup>15</sup>Other studies using a similar approach are Agénor et al. (2018), Rubio and Yao (2017) and Glocker and Towbin (2012).

<sup>16</sup>To save space, Table 3.3 shows only the household loan loss shock. The results for the entrepreneur loan loss shock are qualitatively similar to those for the household loan loss shock. For the optimal policy analysis we use the optimal simple rule (osr) unconstrained optimisation routine in Dynare. A smaller loss function value in the same column implies a more effective policy regime.

when the economy faces technology and financial shocks - the loss function values under the sector-specific regime (5.2991 for the technology shock and 1.2398 for the financial shock) are smaller than those under the generic regime (5.5218 for the technology shock and 1.5406 for the financial shock). When the housing demand shock hits the economy, the generic regime outperforms the sector-specific regime in terms of minimising welfare loss.

The corresponding optimal parameters (the  $\chi_s$ ) are shock dependent for both the generic and the sector-specific regimes. As the table shows, both the household and corporate CcLTV regimes require an aggressive reaction to credit following a financial or a housing demand shock, whereas they require only a moderate reaction to credit following a technology shock. The optimal reaction to output is also moderate under technology and housing demand shocks but slightly stronger under a financial shock. Under the sector-specific regime, the corporate CcLTV requires a stronger response to credit and output than the household CcLTV. That is,  $\chi_{l,me} > \chi_{l,mb}$  and  $\chi_{y,me} > \chi_{y,mb}$ , except when the economy faces a housing demand shock, in which case the household CcLTV requires a stronger reaction to credit than the corporate LTV ( $\chi_{l,mb} > \chi_{l,me}$ ).

Table 3.3 also shows the standard deviations of the three key policy variables (credit, house prices and output) obtained from the optimal CcLTV regimes compared with the baseline regime in which there is no CcLTV (constant LTV ratios). The results show that both the generic and sector-specific CcLTV regimes are effective in minimising the volatility of the three key policy variables, especially for credit. Compared to the generic regime, the sector-specific regime provides a higher degree of macroeconomic stability. This stabilisation effect becomes more significant when the economy faces financial and housing demand shocks.

As a caveat, in interpreting these results it is important to note that the findings in this section only serve to illustrate the effectiveness of the two CcLTV policy regimes. We are not, in any way, suggesting that the authority should be as aggressive as the results suggest. In fact, Schmitt-Grohé and Uribe (2007) note that large values of the optimal policy coefficients are difficult to communicate to policymakers or the public. Rubio and Unsal (2017) note that it is not surprising to obtain large values for the optimal policy parameters, especially when the values of the parameters are not constrained within reasonable ranges in the optimisation exercise, as is the case in this paper.<sup>17</sup> In some cases, the welfare loss (the value of the loss function) can continuously improve even at large values of the policy parameters, but at a very

<sup>17</sup>We do not restrict the values of the parameters in the optimisation exercise because the literature has yet to reach consensus on the reasonable ranges or bands for the parameters in macroprudential policy rules.

slow rate (Rubio and Unsal, 2017). That is, the optimisation exercise can have diminishing marginal stabilisation effects on the welfare loss, to the point where the additional stabilisation effect is negligible and the welfare loss flattens out as the policy parameters increase further.<sup>18</sup>

Table 3.3: Optimal rules: generic versus sector-specific.

Parameter	Technology shock	Financial shock	Housing demand shock
<b>Optimal generic CcLTV rule</b>			
$\chi_{l,m}$	1.8534	22.5042	38.6552
$\chi_{y,m}$	0.9461	3.5905	0.7570
Loss function value ( $\times 10^{-4}$ )	5.5218	1.5406	0.4184
Std. dev. relative to baseline <sup>+</sup>			
$L_t$	0.0617	0.0073	0.0115
$q_t$	0.7836	0.6954	0.8811
$Y_t$	0.9821	0.9268	0.8000
<b>Optimal sector-specific CcLTV rule</b>			
$\chi_{l,m_b}$	1.4663	12.7687	50.1661
$\chi_{y,m_b}$	0.5968	2.4979	0.5730
$\chi_{l,m_e}$	1.9586	34.0370	20.3158
$\chi_{y,m_e}$	1.1799	5.3523	0.9479
Loss function value ( $\times 10^{-4}$ )	5.2991	1.2398	0.4412
Std. dev. relative to baseline <sup>+</sup>			
$L_t$	0.0606	0.0083	0.0115
$q_t$	0.7665	0.6260	0.9055
$Y_t$	0.9643	0.7805	0.6000

<sup>+</sup> This value is calculated as the standard deviation (Std. dev.) of a variable  $i$ ,  $i = \{L, q, Y\}$ , under the generic or sector-specific CcLTV regime divided by that under the baseline model where there is no CcLTV (i.e. the LTV ratios are constant). A value less than 1 means that a particular policy rule reduces the volatility of variable  $i$  relative to the baseline regime.

## 3.6 Impulse response analysis

In this section, to investigate the effectiveness of the two CcLTV regimes and the transmission mechanisms through which they achieve the two objectives of the macroprudential policy, we present the impulse responses of the main variables (shown in Fig. 3.2 to Fig. 3.4) following technology, financial and housing demand shocks. We contrast the baseline regime, defined by constant LTV ratios in Eqs. (3.10) and (3.19), with the optimal generic and sector-specific

<sup>18</sup>In monetary policy studies, Schmitt-Grohé and Uribe (2007) also find that unconstrained optimal policy rules call for a much larger inflation coefficient (about 332) but yield a negligible welfare improvement.

CcLTV regimes.<sup>19</sup> This allows us to investigate whether the sector-specific regime is more effective than the generic one in achieving financial and macroeconomic stability, where there are two types of borrowers from distinct sectors of the credit market. The analysis with the three shocks also enables us to establish whether the effectiveness of the CcLTV depends on the type of shock.

### 3.6.1 Technology shock

Fig. 3.2 shows the impulse responses of the main variables to a positive technology shock under the baseline regime and the generic and sector-specific CcLTV regimes. The shock generates expansionary effects in the economy. Under the baseline regime (the black solid line), it increases the marginal productivity of housing, which in turn increases entrepreneurs' demand for housing and hence house prices. Through the borrowing constraint channel, the rise in house prices stimulates credit growth as the value of the collateral asset increases, and results in an increase in output and consumption. The bank also increases its lending rates, in response to the higher demand for credit.

Turning to the generic (the red dash-dot line) and sector-specific (the blue asterisk line) CcLTV regimes, we find that both regimes imply that the increase in credit and output triggers the household and corporate LTV ratios to decline temporarily. This tightens households' and entrepreneurs' borrowing constraints and reduces the extent of an increase in borrowers' demand for credit and investment in housing. House prices increase less than they did under the baseline regime. In addition to this indirect effect, the CcLTV also has a direct effect on house prices through the borrowers' optimal conditions for housing (Eqs. (3.12) and (3.20)): the fall in the LTV ratios leads directly to a decline in house prices. This further tightens collateral constraints and mitigates the amplification effects of the financial accelerator mechanism (Bernanke et al., 1999).

Both CcLTV regimes are effective in attenuating the impact of the technology shock on financial variables, including house prices, but have limited effects on the real variables (consumption and output). The CcLTV limits the extent to which the borrowers can take on leverage and hence the demand for credit. With the lower demand for credit, lending rates do not need to respond as aggressively as in the baseline regime. The moderate increase in demand for credit, in turn, reduces the borrowers' debt burden, and somewhat enables them to consume

<sup>19</sup>The macroprudential policy parameter values are taken from Table 3.3 in the optimal rule analysis.

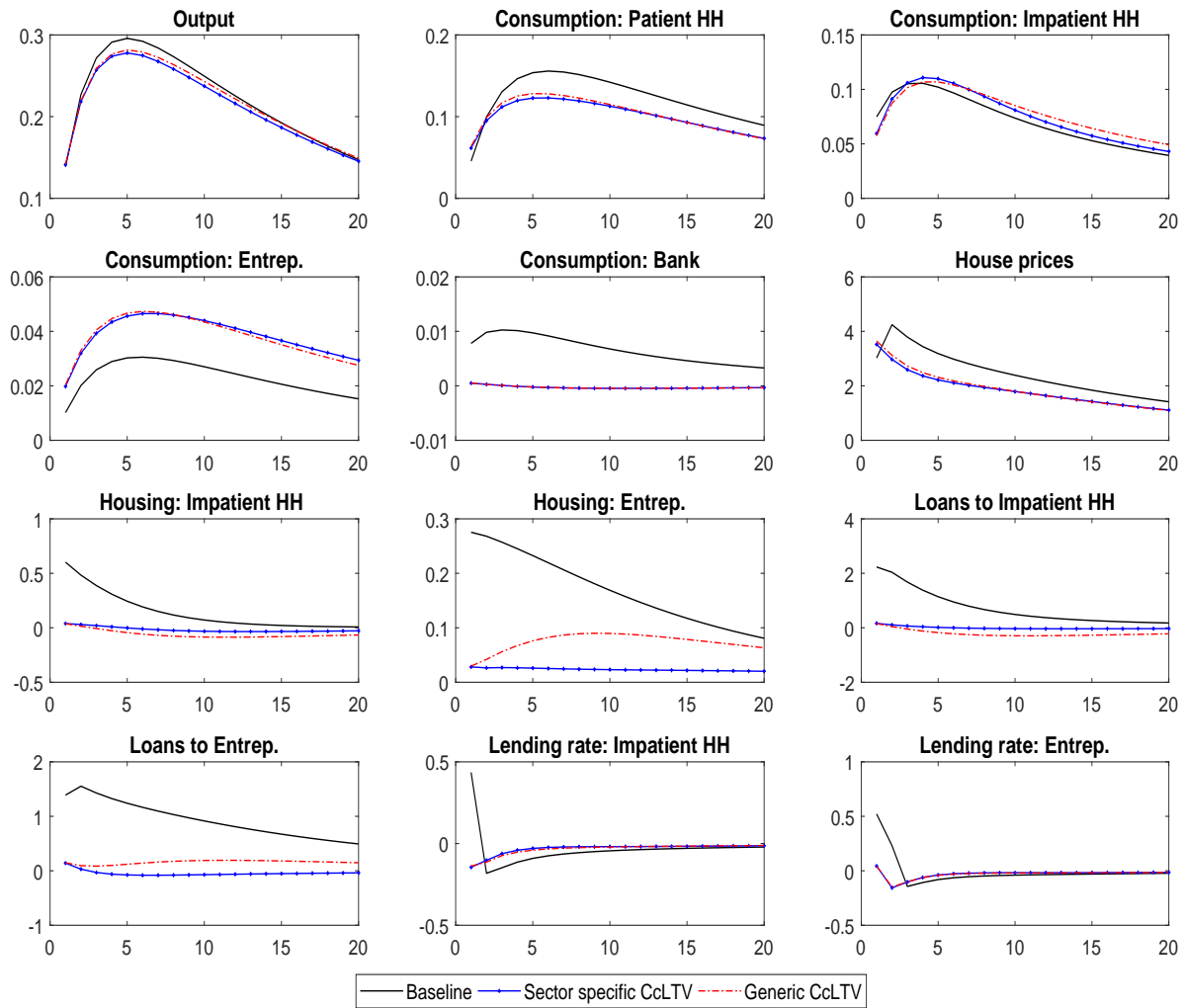


Figure 3.2: Impulse responses to a positive technology shock under the baseline, generic and sector-specific CcLTV regimes. HH and Entrep denote household and entrepreneur, respectively. Variables are expressed in % deviations from the steady state, and interest rates are in annualised percentage points. *Ordinate*: time horizon in quarters.

more under the two CcLTV regimes than under the baseline regime. On the other hand, the moderate increase in credit and deposits, coupled with the fall in interest rates, reduces the bank's and the patient households' interest income. As a result, the bank and the patient households consume less under the CcLTV regimes than under the baseline regime. Therefore, the borrowers' higher consumption compensates for the lower consumption by patient households and the bank, such that the overall impact of the CcLTV on aggregate consumption and hence output becomes limited. These findings are also consistent with the literature (see, e.g., Rubio and Carrasco-Gallego (2014) and Ravn (2016)).

A comparison of the two CcLTV regimes suggests that their effectiveness is more or less the same following the technology shock. However, the sector-specific regime marginally outperforms the generic regime in dampening fluctuations in house prices, aggregate consumption and

output. In the credit and housing markets, Fig. 3.2 shows that the sector-specific CcLTV regime is slightly more effective than the generic regime in dampening fluctuations in entrepreneurs' credit and housing stock while the generic regime outperforms the sector-specific regime in dampening fluctuations in households' credit and housing stock. This is because the optimal implementation of the corporate CcLTV requires a stronger policy response to credit under the sector-specific regime than under the generic regime. However, the optimal household CcLTV requires stronger policy response to credit under the generic regime than under the sector-specific regime.

### 3.6.2 Financial (household loan loss) shock

Fig. 3.3 compares the attenuation effects of the generic and sector-specific regimes following a negative financial shock (modelled as an exogenous increase in bank loan losses on household loans).<sup>20</sup> The negative financial shock causes a recession in the real economy through the spillover from the financial sector. Under the baseline regime, the shock impairs the bank's balance sheets and reduces its net worth. Through the bank's capital constraint channel, this decreases the credit supply to both impatient households and entrepreneurs. Consequently, the demand for housing declines, dragging house prices down. This in turn results in a further decline in credit through the borrowing constraint channel. In an attempt to boost profits and rebuild net worth, the bank increases its lending rates. This further depresses the demand for credit, reduces aggregate consumption and results in a protracted recession.

The presence of CcLTV mitigates the recessionary effect of the financial shock. Under both the generic and sector-specific regimes, the fall in credit and output activates the CcLTV. The LTV ratios increase temporarily, leading to an increase in the value of collateral assets (housing). This enables borrowers to borrow more out of their housing wealth and therefore mitigates the decline in demand for credit. As a result, the fall in borrowers' demand for housing, and hence the fall in house prices, becomes smaller under the CcLTV than under the baseline regime. This, in turn, dampens the amplification effects of the borrowing constraint channel. Consequently, the extent of the increase in lending rates becomes smaller under both CcLTV regimes than under the baseline regime. The recessionary effect of the shock becomes less pronounced.

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<sup>20</sup>Here we only report the results of the household loan loss shock. The results are similar for the entrepreneurs' loan loss shock except that the entrepreneurs' consumption increases while that of the borrower households declines.



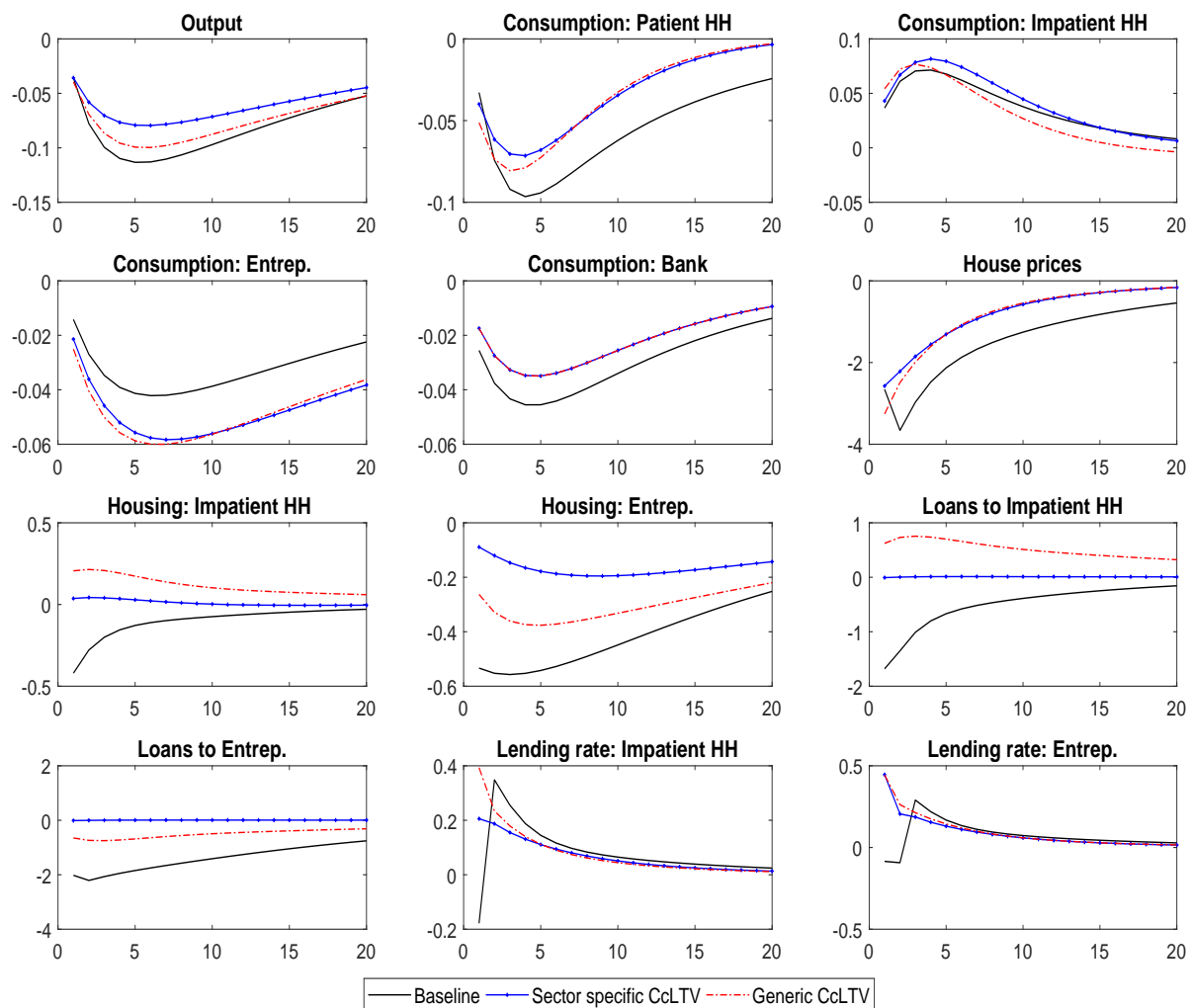


Figure 3.3: Impulse responses to a negative financial shock (household loan loss shock only) under the baseline, generic and sector-specific CcLTV regimes. HH and Entrep denote household and entrepreneur, respectively. Variables are expressed in % deviations from the steady state, and interest rates are in annualised percentage points. *Ordinate*: time horizon in quarters.

The results further show that the CcLTV affects consumption by the different agents (patient and impatient households, entrepreneurs and the bank) asymmetrically. For borrowers, the increase in the LTV ratios mitigates the decline in demand for credit and this effectively increases their debt service burden more than the baseline regime does. As a result, the increase in the impatient households' consumption is reduced while the entrepreneurs' consumption drops further.<sup>21</sup> Similarly, the attenuation effect of the CcLTV mitigates the fall in the patient households' and the bank's consumption by reducing the fall in their interest income.

Comparing the impact of the two CcLTV regimes, we find that the sector-specific regime is

<sup>21</sup>For household borrowers, the shock increases their income indirectly. By paying less than the contractual amount of the loan, household borrowers are able to spend more than previously anticipated. The results in Fig. 3.3 are based on household loan loss shock only. This shock does not have an indirect income effect on entrepreneurs' consumption.

more effective than the generic CcLTV regime in mitigating the fall in the entrepreneurs' credit and hence their demand for housing. On the other hand, the generic CcLTV regime is more effective in mitigating the fall in the impatient households' credit and their demand for housing. This is because the optimal implementation of the household CcLTV requires a stronger policy response to credit under the generic regime than under the sector-specific regime. However, the optimal corporate CcLTV requires a stronger policy response to credit under the sector-specific regime than under the generic regime. Compared to the case of the technology shock, Fig. 3.3 shows that the sector-specific regime significantly outperforms the generic regime in dampening the fluctuations in aggregate consumption, output and house prices. In this case, the extent of over-reaction in the household credit market sector and under-reaction in the corporate credit market sector under the generic regime is more pronounced. Instead of mitigating the fall in household credit, the generic regime causes it to increase.

It is important to note that when only one sector of the credit market is hit by a negative financial shock (in this case the household loan market), the sector-specific CcLTV regime plays a very important role in stabilising the financial sector. We can see this because when we implement the sector-specific regime rather than the generic regime, the CcLTV regime moderately mitigates the decline of household credit while significantly stabilising corporate credit. Consequently, the negative effect of the shock on entrepreneurs' consumption under the sector-specific regime is less than under the generic regime. At the same time, the sector-specific CcLTV regime has a larger positive impact on impatient households' consumption. This, in turn, contributes significantly to macroeconomic stability – output recovers significantly under the sector-specific regime.

### 3.6.3 Housing demand shock

Fig. 3.4 shows the impulse responses of the main variables following a positive housing demand shock. As with the case of a positive technology shock, the shock generates expansionary effects in the economy, leading to an increase in the demand for housing and in house prices. Through the collateral constraint channel, the increase in house prices allows borrowers to increase their borrowing and stimulates aggregate consumption and output.<sup>22</sup> In response to the higher demand for credit, the bank also increases its lending rates.

<sup>22</sup>At disaggregate level, the shock leads to an initial fall in household savers' consumption. This is because the increase in the return to deposits creates an incentive for them to increase savings and forgo consumption.

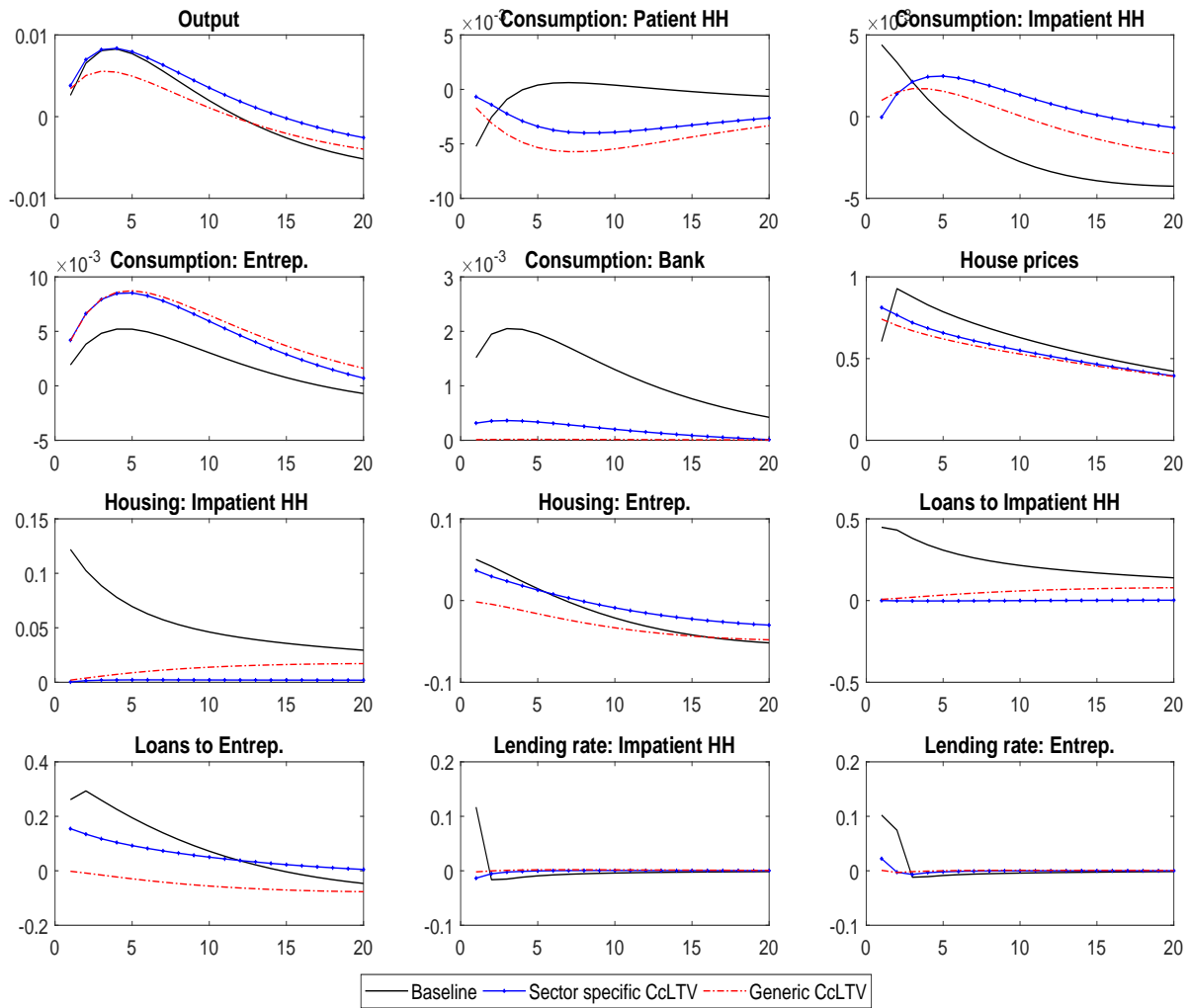


Figure 3.4: Impulse responses to a positive housing demand shock under the baseline, generic and sector-specific CcLTV regimes. HH and Entrep denote household and entrepreneur, respectively. Variables are expressed in % deviations from the steady state, interest rates in annualised percentage points. *Ordinate*: time horizon in quarters.

Under the two CcLTV regimes, the regulatory authority decreases the LTV ratios in response to the increase in credit and output, and this reduces the increase in house prices and the demand for credit through the borrowing constraint channel. Since the CcLTV reduce the increase in borrowing and lending rates, the borrowers' debt service costs decline. This, in turn, allows borrowers to consume more than they did under the baseline regime. Similarly, the interest income accruing to both the bank and the patient households falls and this causes a fall in the patient households' consumption and reduces the increase in the bank's consumption.

Unlike the effect we saw in the case of a negative financial shock, the generic regime is more effective than the sector-specific regime in reducing fluctuations in output and house prices. Indeed, except for the impatient households' credit and housing, the generic regime

outperforms the sector-specific regime in achieving financial and macroeconomic stability.<sup>23</sup> This implies that when both sectors of the credit market are hit by the same shock, the generic regime is more effective than the sector-specific regime. In the case of a housing demand shock, since the CcLTV works through the borrowing constraint channel and housing is used as a collateral asset for both types of borrowers, the shock affects both types of borrowers in the same way. The regulatory authority can, therefore, implement the generic CcLTV regime accordingly. In this way, the authority can achieve its macroprudential policy objectives of financial and macroeconomic stability.

### 3.7 Efficient policy frontier

In this section, we present the outcome of the generic and the sector-specific regimes in the form of a two-dimensional efficient policy frontier on credit and output. The efficient policy frontier shows the locus of the volatility of credit and output calculated at each set of optimal policy coefficients that are obtained for different combinations of loss function weights. To perform the exercise, we simplify the loss function (3.46) by setting the weight on the volatility of house prices to zero,  $\lambda_q = 0$ , and allow the weights on credit and output to vary inversely within the range  $\lambda \in [0, 1]$ . That is:

$$\mathcal{L}_{mp} = \lambda \sigma_l^2 + (1 - \lambda) \sigma_y^2. \quad (3.47)$$

For each combination of the loss function weights, we compute the set of optimal policy coefficients that yields the lowest welfare loss and then plot the corresponding volatility of credit and output in a two-dimensional plot, as shown in Fig. 3.5.<sup>24</sup> Moving from left to right in Fig. 3.5, the weight on the volatility of credit ( $\lambda$ ) increases from 0 to 1 while that on volatility of output decreases from 1 to 0.

The efficient policy frontiers under the two alternative policy regimes present a clear trade-off between financial and macroeconomic stability, as the authority adjusts its preference between the two policy objectives. The maximum attainable reduction in output volatility can be achieved at the expense of increasing credit volatility. Compared with the baseline regime (the small black square), the two alternative CcLTV regimes can virtually eliminate credit volatility

<sup>23</sup>This is because the optimal household CcLTV rule requires a stronger response to credit under the sector-specific regime than under the generic regime.

<sup>24</sup>The analysis is conducted for financial shock. We perform a similar exercise for the other two shocks (technology and housing demand) and obtain similar results. These results are reported in appendix B.3.

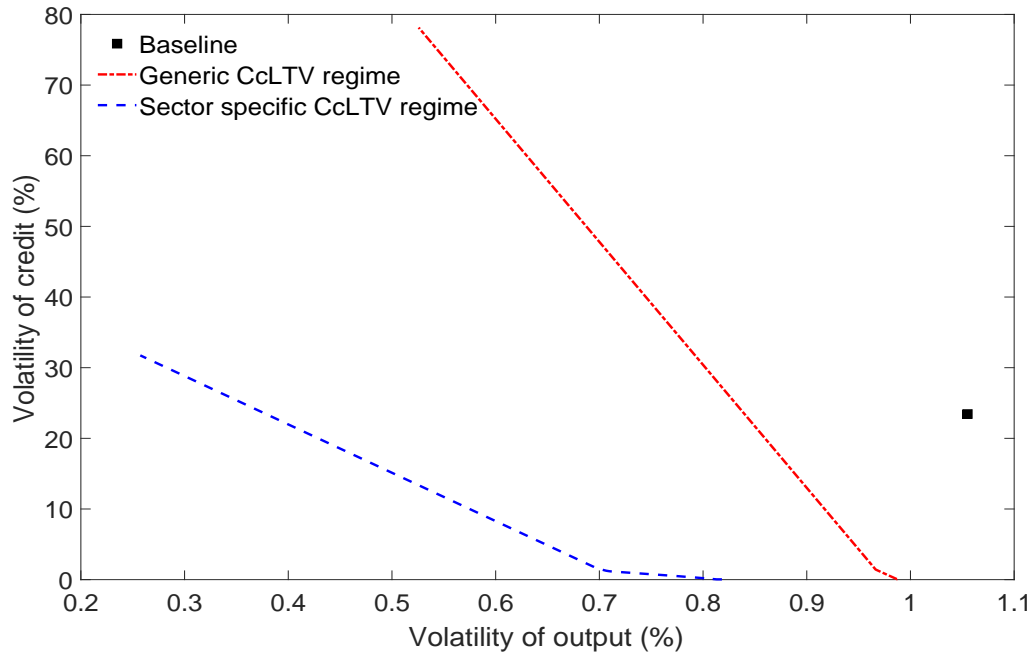


Figure 3.5: The efficient policy frontier ( $\lambda \in [0, 1]$ ).

without increasing output volatility. This means that, compared to the baseline case, the two policy regimes can achieve the maximum attainable financial stability benefits without compromising macroeconomic stability.

A comparison between the two CcLTV regimes suggests that the sector-specific CcLTV regime is more effective than the generic CcLTV regime in stabilising both credit and output volatility. Furthermore, the sector-specific regime can deliver a larger reduction in output volatility at a lower cost of financial instability. This can be seen in the flatter frontier. In summary, the results suggest that the appropriate implementation of CcLTV has the potential to deliver both financial and macroeconomic stability. This concurs with the findings in Brzoza-Brzezina et al. (2015) and Rubio and Yao (2017), in which the authors establish that the CcLTV reduces the volatility of both credit and output. The sector-specific regime delivers a more stable economic system than the generic regime.

### 3.8 Implementing the CcLTV regulation: generic versus sector-specific rules

To understand better how the proposed CcLTV regimes work, we simulate the model with different values of parameters in the policy rules Eqs. (3.41) and (3.42) and trace the impact

on the volatility of credit, house prices and output. This exercise demonstrates the possible trade-off between financial stability and macroeconomic stability when the regulatory authority responds more aggressively to changes in credit and output. To perform this exercise, we allow the two policy parameters to vary and plot the variance surfaces of credit, house prices and output against these two parameters.<sup>25</sup>

Fig. 3.6 shows the results for the generic CcLTV regime. The first two panels show that this regime is effective in delivering financial stability. A more aggressive response to aggregate credit (movement along  $\chi_{lm}$ -axis) leads to a substantial fall in the volatility of aggregate credit and house prices. Nonetheless, this stabilisation benefit diminishes as the policy becomes more aggressive. The mesh plots further show that a more aggressive response to changes in output (movement along  $\chi_{ym}$ -axis) can only enhance financial stability with a moderate response to changes in credit (with  $\chi_{lm} < 2$ ). The third panel of Fig. 3.6 shows that the generic CcLTV regime has a potential to deliver macroeconomic stability if authority adjusts the LTV ratios to changes in output more aggressively ( $\chi_{y,m} \Rightarrow 2$ ), but only marginally to changes in credit ( $\chi_{l,m} \Rightarrow 0$ ).

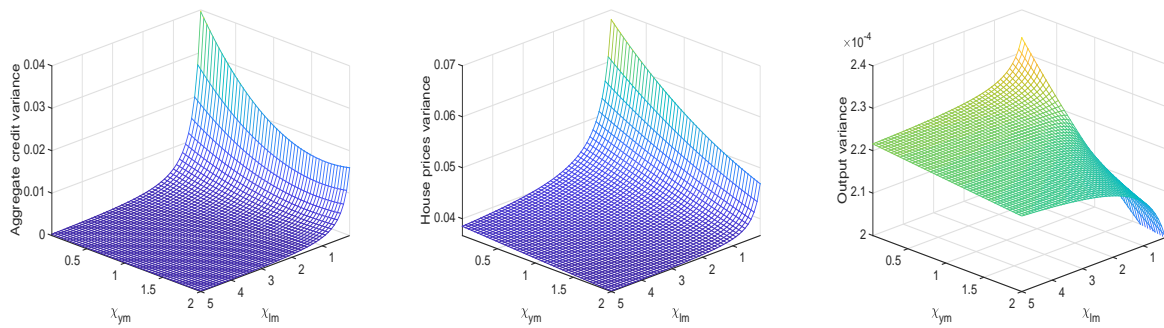


Figure 3.6: Policy response impact (different values of  $\chi_{lm}$  and  $\chi_{ym}$ ): generic CcLTV regime.

Figs. 3.7 and 3.8 show the results for the sector-specific CcLTV. In this case, we perform the same exercise with household and corporate CcLTV independently. That is, we perform the simulation exercise with the household (corporate) CcLTV while holding the corporate (household) LTV ratio constant. Fig. 3.7 shows the results for the household CcLTV rule and Fig. 3.8 shows the volatility of corporate credit, as opposed to the aggregate credit.

<sup>25</sup>We simulate the model with all the shocks and perform the grid search over the ranges  $\chi_{l,m} = [0, 5]$  and  $\chi_{y,m} = [0, 2]$  with the grid step of 0.1 and 0.04 for  $\chi_{l,m}$  and  $\chi_{y,m}$ , respectively, as these are sufficient for the purpose of this paper. In a separate exercise, we also experiment with the values of  $\chi_{l,m} > 5$  and  $\chi_{y,m} > 2$ . The same conclusion emerges.

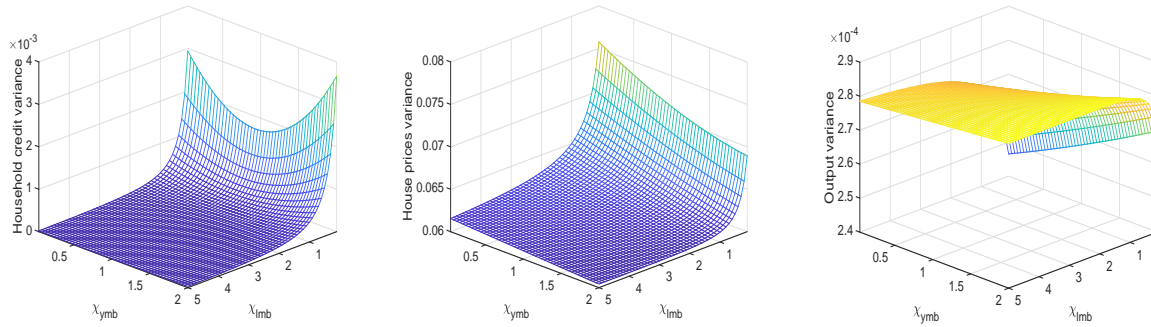


Figure 3.7: Policy response impact (different values of  $\chi_{lmb}$  and  $\chi_{ymb}$ , given  $\chi_{lme} = \chi_{yme} = 0$ ): sector-specific CcLTV regime.

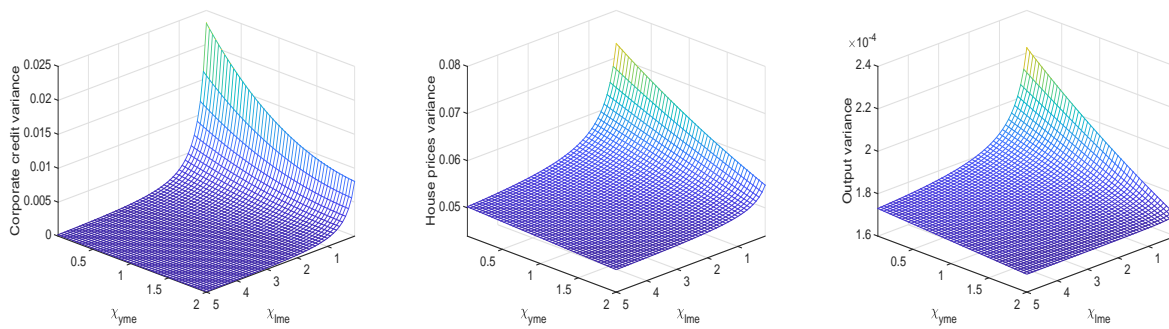


Figure 3.8: Policy response impact (different values of  $\chi_{lme}$  and  $\chi_{yme}$ , given  $\chi_{lmb} = \chi_{ymb} = 0$ ): sector-specific CcLTV regime.

The results are similar to those for the generic CcLTV regime. However, the effect of the response to changes in output on sector-specific credit differs for household credit and corporate credit. With a moderate response to sector-specific credit, the stabilisation effect of the response to changes in output on corporate credit increases monotonically as it becomes more aggressive. For household credit, however, this effect increases only up to  $\chi_{ymb} = 1.5$ , and thereafter it becomes weaker - the volatility of household credit starts increasing. Another difference is that the corporate CcLTV enhances macroeconomic stability when the regulation becomes more aggressive to changes in corporate credit and output, whereas an aggressive household CcLTV does not improve macroeconomic stability.

The general conclusion to be drawn from this exercise is that the proposed CcLTV regimes have the potential to deliver on financial and macroeconomic stability mandates. However, this stabilisation effect on financial stability diminishes if the regulator responds aggressively to changes in credit. Responses to changes in output can achieve financial stability only if the regulator responds to changes in financial variables moderately. However, regardless of whether the regulatory authority responds to changes in output aggressively or not, an aggres-



sive response to changes in credit does not contribute to macroeconomic stability, whereas a moderate response to changes in credit has a significant impact.

### 3.9 Conclusion

This paper considered the optimal design and the implications of the CcLTV regulation in a model economy where there are two types of borrowers from distinct sectors of the credit market. We looked at two policy regimes, generic and sector-specific, and compared their effectiveness in enhancing financial and macroeconomic stability. We found that both regimes are effective, especially when the economy is hit by financial and housing demand shocks. This is achieved mainly by reducing the amplification effects of the borrowing constraint channel. The effectiveness of both regimes is, however, shock dependent. When the economy faces a technology shock, their effectiveness is more or less the same. When the economy faces a financial shock, the sector-specific regime significantly outperforms the generic regime in reducing business cycle fluctuations, whereas the opposite is true when the economy is hit by a housing demand shock. The efficient policy frontiers under the two alternative policy regimes present a clear trade-off between financial and macroeconomic stability, as the authority adjusts its preference between the two policy objectives. The sector-specific CcLTV regime is more effective than the generic CcLTV regime in reducing the volatility of credit and output.

Our findings highlight the importance of identifying the origin of the shock in order to implement the CcLTV regulation appropriately. More importantly, our findings suggest that, in order to enhance the effectiveness of the macroprudential policy, the regulator should consider borrowers' heterogeneity and tailor the CcLTV regulation according to the specific conditions of each sector of the credit market, rather than to the aggregate credit market condition. In this way, the regulator can directly target the credit market sector, or the borrower type, where systemic risk is developing.



## Chapter 4

# The optimal monetary and macroprudential policies for the South African economy

### 4.1 Introduction

The main objective of macroprudential policy is to prevent the build-up of systemic risk in the financial markets. Since the 2007/08 financial crisis, most central banks around the world, including the South African Reserve Bank, have expanded their mandate by adding a financial stability objective to the macroeconomic (price) stability objective.<sup>1</sup> This presents a new challenge for central banks - how to achieve the optimal interaction between monetary and macroprudential policies. The difficulty is that the two policies mutually affect each other. While macroprudential policy provides a channel through which central banks promote financial stability, at the same time it affects macroeconomic conditions and the performance of other policies, especially monetary policy. For example, through its effect on credit growth, macroprudential policy affects monetary conditions and hence the conduct of monetary policy. Similarly, monetary policy can affect credit conditions through its interest rate channel.

The goals of monetary and macroprudential policies are mutually dependent. The literature has yet to find common ground on how central banks should coordinate monetary and macroprudential policies to facilitate a simultaneous pursuit of macroeconomic and financial

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<sup>1</sup>Jeanneau (2014) surveys 114 central bank laws and statutes and establishes that approximately 82% of central banks have an explicit financial stability objective. The South African Reserve Bank enacted the explicit mandate of maintaining and enhancing financial stability in 2017, through the Financial Sector Regulation Act 9 of 2017.

stability. One strand of the literature examines the way a standard monetary policy that reacts to inflation and output interacts with macroprudential policy (e.g., Angelini et al., 2014; Quint and Rabanal, 2014; Rubio and Carrasco-Gallego, 2014, 2016). The general conclusion of these studies is that a combination of a standard monetary policy and macroprudential policy is effective in enhancing macroeconomic and financial stability, especially when the economy faces housing market and financial market shocks. Using a general equilibrium framework with endogenous credit risk, Tayler and Zilberman (2016) establish that a policy regime combining a strong anti-inflation monetary policy and an aggressive macroprudential policy that reacts to credit risk is effective in enhancing financial and macroeconomic stability when the economy is facing a technology (non-financial) shock. In a nutshell, these studies suggest that a policy regime in which monetary policy is exclusively assigned to the price stability objective while macroprudential policy is exclusively assigned to the financial stability objective facilitates a simultaneous pursuit of both macroeconomic and financial stability. This finding is consistent with studies that advocate a separation of responsibilities for monetary and macroprudential policies, such as Svensson (2012), Gelain et al. (2013), Suh (2014), Svensson (2017) and Turdaliev and Zhang (2019).

Another strand of the literature establishes an augmented monetary policy that reacts to financial variables, such as credit, interest rate spread and asset prices, in addition to inflation and output, and examines its interaction with macroprudential policy (e.g., Kannan et al., 2012; Angeloni and Faia, 2013; Agénor et al., 2013; Lambertini et al., 2013; Mendicino and Punzi, 2014; Bailliu et al., 2015). These studies suggest that a policy regime that combines an augmented monetary policy and macroprudential policy enhances macroeconomic and financial stability. Curdia and Woodford (2010), Gambacorta and Signoretti (2014), Verona et al. (2017) and Adrian and Liang (2018) argue that monetary policy should aim to achieve the broader objective of overall economic stability rather than the narrower one of price stability alone. In contrast, Benes and Kumhof (2015), Tayler and Zilberman (2016) and Turdaliev and Zhang (2019) show that a monetary policy rule that reacts to financial imbalances causes welfare to deteriorate, irrespective of whether it is implemented in conjunction with macroprudential policy and irrespective of what kind of shock is hitting the economy.

This paper is the first of its kind to investigate the interaction between monetary and macroprudential policies in South Africa. Most of the literature examines the interaction between monetary and macroprudential policies in developed economies and little research has been

done on emerging market economies like South Africa.<sup>2</sup> One of the few studies that examine the interaction between monetary and macroprudential policies in the context of developing economies is Agénor et al. (2013). In South Africa, bank lending is more or less equally distributed between households and corporates. The South African credit market data show that over the period 2000Q1–2016Q4 the average ratio of household loans to total bank loans was 52% while that of corporate loans to total bank loans was 48%. In addition, the two types of credit behaved differently in the past.<sup>3</sup> Therefore, a framework with heterogeneous borrowers allows us to examine the impact of a broader range of financial shocks emanating from different sectors of the credit market and the stabilisation effect of monetary and macroprudential policies in South Africa. This comprises the second contribution of the paper.

The paper also contributes to the literature by examining the optimal interaction between monetary and macroprudential policies in a framework where heterogeneous borrowers (households and non-financial corporates) from distinct sectors of the credit market co-exist. Most of the literature focuses on the interaction between the two policies in a framework where there is only one type of borrower: either household or non-financial corporate. We argue that policy analysis based on this kind of framework is likely to miss some of the key transmission channels and the trade-off between macroeconomic and financial stability in the economy, and is therefore less informative for policymakers. Angelini et al. (2014) is one of the few studies which examine the interaction between monetary and macroprudential policies in a framework where household and non-financial corporate borrowers co-exist. In contrast to Angelini et al. (2014), we also consider a monetary policy rule that reacts to credit growth and study its interaction with macroprudential policy. Furthermore, our analysis considers three types of financial shock: housing demand, loan-to-value (LTV) and non-performing loan (NPL) shock.

The main objective of the paper is to determine the optimal design of a simultaneous deployment of monetary and macroprudential policies and investigate its effectiveness in enhancing macroeconomic and financial stability. We measure macroeconomic stability in terms of the volatility of inflation, and financial stability in terms of the volatility of credit-to-output ratio and house prices, in line with Rubio and Carrasco-Gallego (2014) and Agénor and Pereira da Silva (2017). We consider two alternative policy regimes, in which monetary and macropru-

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<sup>2</sup>A non-exhaustive list is Kannan et al. (2012), Angeloni and Faia (2013), Lambertini et al. (2013), Angelini et al. (2014), Rubio and Carrasco-Gallego (2014), Quint and Rabanal (2014), Mendicino and Punzi (2014), Bailliu et al. (2015), Benes and Kumhof (2015), Rubio and Carrasco-Gallego (2016), Tayler and Zilberman (2016), Gelain and Ilbas (2017) and Turdaliev and Zhang (2019).

<sup>3</sup>See Chapter 3 for a detailed discussion.

dential policies are jointly implemented, and compare their effectiveness against a benchmark regime in which there is only monetary policy. The macroprudential policy considered in this study is a countercyclical capital requirement (CcCR) rule that relates the bank capital requirement ratio to deviations of the credit-to-output ratio from its steady state, which is in line with Basel III countercyclical capital buffers. In the benchmark regime (regime I), monetary policy follows a standard Taylor-type interest rate rule that relates the policy rate to inflation and output growth. There is no macroprudential rule in regime I, and the capital requirement ratio is constant. The first alternative policy regime (regime II) is a combination of a standard Taylor rule and the CcCR rule. The second alternative policy regime (regime III) is a combination of an augmented Taylor rule and the CcCR rule. The augmented Taylor rule relates the policy rate to credit growth in addition to inflation and output growth. Under regime III, we also investigate whether monetary policy should promote financial stability in addition to its primary objective of price stability.

To conduct our analysis, we first develop a New Keynesian dynamic stochastic general equilibrium (DSGE) model with financial frictions, a housing market, a stylised banking sector and the role of monetary and macroprudential policies. Specifically, we add price stickiness to Iacoviello (2015) model, which allows us to study the price stabilising effect of the monetary policy. Second, in line with Bouvatier and Lepetit (2012), we introduce endogenous loan losses in the model by assuming borrowers do not repay a proportion of loans borrowed from the previous period. This is in contrast to Iacoviello (2015), in which the author assumes that loan losses are exogenous. Lastly, we incorporate the role of macroprudential policy into the model.

We first estimate the model using Bayesian techniques with South African data over the sample period 2000Q1–2016Q4. Based on the estimated results, we then derive the optimal combination of monetary and macroprudential policy rules assuming the central bank minimises a policy loss function. The loss function is in terms of a weighted sum of the volatility of inflation, output, credit-to-output ratio and house prices.<sup>4</sup> We find that, to achieve financial and macroeconomic stability objectives, the optimal monetary policy rule requires a smaller response to inflation and a bigger response to output than the estimated responses under the benchmark regime. The optimal macroprudential policy rule requires the central bank to adjust

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<sup>4</sup>We assume that monetary and macroeconomic policies are conducted under full coordination, i.e., the two policies are used to minimise the same objective function. We leave aside a case where there are two policymakers each assigned a separate mandate: a central bank assigned a macroeconomic stability mandate and a macroprudential authority assigned a financial stability mandate. We do not attempt to study the interaction between monetary and macroprudential policies in a non-cooperative setting. This is beyond the scope of this paper and therefore left for future research.

the capital requirement ratio proportionately to deviations of the credit-to-output ratio from the steady state, irrespective of whether it is jointly deployed with a standard monetary policy rule or an augmented monetary policy rule. Regime III delivers the highest welfare gains, but at a much higher cost of increasing inflation volatility.

Based on the optimal policy rules derived previously, we then compare the dynamics of the model under the three policy regimes, following housing demand, LTV and NPL shocks. We find that a simultaneous deployment of the optimal monetary and macroprudential policy rules attenuates fluctuations in the housing market, the credit market and the real sector. A policy regime that combines a standard monetary policy rule and macroprudential policy rule (regime II) delivers a more stable economic system than a regime that combines an augmented monetary policy rule and macroprudential policy rule (regime III). The central bank faces a more severe trade-off between price and financial stability when monetary policy also responds to credit growth. While this policy regime seems to be effective from the financial stability point of view, it can compromise price stability (Taylor and Zilberman, 2016). This is especially the case when shocks generate a negative correlation between credit and inflation. As we note in our analysis, a housing demand, LTV or NPL shock generates a negative correlation between credit and inflation. The central bank is forced to choose between price stability or financial stability when deploying an augmented monetary policy rule. The policy rate response required to achieve price stability is inconsistent with that required to achieve financial stability. For example, a positive housing demand shock increases credit but reduces inflation. The reduction in inflation calls for a reduction in the policy rate, but a boom in the credit market calls for an increase in the policy rate. This conflict compromises the central bank's ability to deliver on its price stability mandate. Nevertheless, the trade-off between price and financial stability is minimised and the policy conflict is absent under regime II.

Lastly, we perform a policy frontier analysis to assess the efficiency of a simultaneous deployment of monetary and macroprudential policies under the three policy regimes. We see that the introduction of macroprudential policy enhances both financial and price stability. A comparison between regime II and regime III suggests that regime II is more efficient than regime III in promoting financial and price stability. The efficient policy frontiers under the three policy regimes present a clear trade-off between inflation and credit-to-output ratio volatilities, as the central bank adjusts its preference for stabilising the credit-to-output ratio relative to stabilising inflation. The maximum attainable reduction in credit-to-output volatility can be achieved at

the expense of increasing inflation volatility. The relatively inelastic efficient policy frontiers, especially when the economy faces a housing demand shock, imply that it is not wise for the central bank to put a relatively high weight on the credit-to-output ratio in its loss function. This is because a marginal reduction in the volatility of the credit-to-output ratio is achieved at a relatively high cost in terms of the volatility of inflation.

The rest of the paper is organised as follows. Section 4.2 describes the model and Section 4.3 discusses the model estimation strategy and presents the estimation results. Section 4.4 describes the model's business cycle properties. Section 4.5 studies the optimal combination of monetary and macroprudential policies under the two alternative policy regimes and compares their effectiveness in enhancing financial and macroeconomic stability. Section 4.6 reports the results of the impulse response analysis and Section 4.7 the results of the efficient policy frontier analysis. Section 4.8 concludes.

## 4.2 The model

We construct a closed economy New Keynesian DSGE model.<sup>5</sup> The model economy is populated by two types of households (patient and impatient), entrepreneurs, retailers, banks and a central bank. The two types of households work and consume final consumption goods and housing services. In equilibrium, patient households are savers while impatient households are borrowers. Entrepreneurs produce intermediate goods using labour and housing (commercial real estate) as inputs.<sup>6</sup> They also consume final consumption goods and borrow from banks. The two types of borrowers (impatient households and entrepreneurs) face a borrowing constraint which ties the amount of borrowing to the expected value of collateral assets (housing stock). Retailers are the source of nominal rigidity in the model. They buy intermediate goods from entrepreneurs and transform them into final consumption goods. Banks mediate funds between savers and borrowers. Banks are subject to the capital requirement constraint. While the constraint limits banks' ability to provide loans to borrowers, it also constrains the amount of deposits they can take from savers. The central bank implements monetary and macropru-

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<sup>5</sup>We opt for a closed economy model for the following reasons. First, the purpose of this study is to investigate the optimal design and the effectiveness of a simultaneous deployment of monetary and macroprudential policies, not the impacts of external shocks on the domestic economy. Second, activities of the South African credit market are largely confined to the domestic economy. Last, the banking sector has a relatively low exposure to foreign currency. The average ratio of foreign currency deposits to total liabilities is approximately 4.6% while the ratio of foreign currency loans to total assets is approximately 5.0% over the period 2008Q1–2016Q4 (SARB, 2018).

<sup>6</sup>Entrepreneurs represent non-financial corporates or firms.

dential policies to safeguard macroeconomic and financial stability.

### 4.2.1 Patient Households (Savers)

The representative patient household maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left[ (1 - \eta_s) \log(C_{s,t} - \eta_s C_{s,t-1}) + j A_{j,t} \log(H_{s,t}) + \tau \log(1 - N_{s,t}) \right], \quad (4.1)$$

where  $E_0$  is the expectation operator and  $\beta_s \in (0, 1)$  is the household's subjective discount factor.  $C_{s,t}$  is consumption,  $H_{s,t}$  is housing stock and  $N_{s,t}$  is supply of labour (hours of work).<sup>7</sup>  $j$  and  $\tau$  are weights of housing and leisure ( $1 - N_{s,t}$ ) in the utility function, respectively.  $A_{j,t}$  is the housing demand shock that evolves according to the following law of motion:

$$\log A_{j,t} = \rho_j \log A_{j,t-1} + \xi_{j,t}, \quad (4.2)$$

where  $\rho_j$  is a parameter representing the persistence of the shock.  $\xi_{j,t} \sim i.i.d.N(0, \sigma_j^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_j^2$ .

In each period, the household accumulates housing stock,  $H_{s,t}$ , makes deposits,  $D_t$ , at the bank and supplies labour to entrepreneurs and earns real wage rate  $w_{s,t} \equiv W_{s,t}/P_t$ , where  $W_{s,t}$  is nominal wage rate and  $P_t$  is aggregate price level. The household also receives lump-sum transfers in the form of profits,  $F_{s,t}$ , from the retailers. The patient household owns retail firms. The household's budget constraint is given by:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = w_{s,t}N_{s,t} + \frac{R_{t-1}}{\pi_t}D_{t-1} + F_{s,t}, \quad (4.3)$$

where  $q_t \equiv Q_t/P_t$  is real house prices and  $Q_t$  is nominal house prices.  $\pi_t = P_t/P_{t-1}$  is gross inflation rate.  $R_{t-1}/\pi_t$  is the real gross return on a one-period risk-free deposit, where  $R_t$  is the nominal deposit rate, which is equal to the policy rate set by the central bank.  $F_{s,t} = \frac{X_t-1}{X_t}Y_t$ , where  $X_t$  is the markup charged by the retail firms and  $Y_t$  is output.

Let  $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t}-\eta_s C_{s,t-1}}$  be the marginal utility of consumption. The first order conditions which define the household's problem are as follows:

$$1 = \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \frac{R_t}{\pi_{t+1}} \right), \quad (4.4)$$

<sup>7</sup>In the utility function,  $H_{s,t}$  represent consumption of housing services which is proportional to housing stock. Consumption appears in the utility function relative to external habit formation, with  $\eta_s$  measuring degree of habit persistence. In line with Iacoviello (2015) and Guerrieri and Iacoviello (2017), the scaling factor  $1 - \eta_s$  ensures that the marginal utility of consumption is independent of habit parameter in steady state.



$$q_t = j \frac{A_{j,t}}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} q_{t+1} \right), \quad (4.5)$$

$$w_{s,t} = \frac{\tau}{(1 - N_{s,t}) U_{Cs,t}}. \quad (4.6)$$

Eq. (4.4) is the standard Euler equation for consumption, which describes the consumption-saving decision. Eq. (4.5) is the asset pricing equation for housing, which equates the marginal cost of housing to its marginal benefit. Eq. (4.5) can also be interpreted as the patient household's demand for housing. Eq. (4.6) is the household's labour supply condition. It equates the real wage rate to the marginal rate of substitution between consumption and leisure.

### 4.2.2 Impatient Households (Borrowers)

Like the patient household, the representative impatient household maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[ (1 - \eta_b) \log(C_{b,t} - \eta_b C_{b,t-1}) + j A_{j,t} \log(H_{b,t}) + \tau \log(1 - N_{b,t}) \right], \quad (4.7)$$

where  $\beta_b$  is the impatient household's subjective discount factor such that  $\beta_b < \beta_s$ .  $C_{b,t}$  is consumption,  $H_{b,t}$  is housing stock and  $N_{b,t}$  is labour supply. The household's budget constraint is given by:

$$C_{b,t} + \frac{R_{b,t-1}}{\pi_t} (1 - \zeta_{b,t} (1 - \vartheta_b)) L_{b,t-1} + q_t (H_{b,t} - H_{b,t-1}) = w_{b,t} N_{b,t} + L_{b,t}, \quad (4.8)$$

where  $L_{b,t}$  is bank loans to the household, which accrue a real gross interest rate of  $R_{b,t-1}/\pi_t$ .  $w_{b,t}$  is the real wage rate for the household.  $\zeta_{b,t}$  is a fraction of household NPLs which captures partial defaults by the household on loan contract. Following Iacoviello (2015) and Zhang (2019), we introduce  $\zeta_{b,t}$  in line with the literature on the wealth re-distribution (transfer) effect. For the household, an increase in the fraction of NPLs represents an indirect increase in wealth (income gain). This is because by paying less than the agreed amount on the loan contract, the household is able to spend more than previously anticipated. For the bank (the lender), the increase in the fraction of NPLs increases the losses on the bank's loan portfolio and thus reduces the bank's wealth (income). The same variable appears in the bank's budget constraint, but with a negative sign (or on the expenditure side of the budget constraint). Following Bouvatier



and Lepetit (2012), we assume that  $\zeta_{b,t}$  is endogenous and depends on general economic conditions (output growth).<sup>8</sup> We argue that NPLs (loan defaults) are symptoms (manifestations) of distress elsewhere in the economy, such as deteriorating economic conditions that reduce borrowers' ability to repay loans. This modification also allows us to mimic a real world setting and introduces an additional macro-financial feedback loop into the model, in which deteriorating macroeconomic and financial conditions become mutually reinforcing. Specifically, the fraction of household NPLs evolves as follows:

$$\zeta_{b,t} = \zeta_b (\zeta_{b,t-1})^{\rho_{\varepsilon b}} (Y_t/Y_{t-1})^{-\chi_{\zeta b}} e^{\xi_{\varepsilon b,t}}, \quad (4.9)$$

where  $\zeta_b$  is the steady-state value of household NPLs and  $\chi_{\zeta b} > 0$  measures the elasticity of the NPLs with respect to output growth.  $\rho_{\varepsilon b}$  measures the persistence of the NPLs.  $\xi_{\varepsilon b,t}$  is an independent and identically distributed (i.i.d.) NPL shock with mean zero and variance  $\sigma_{\varepsilon b}^2$ . That is,  $\xi_{\varepsilon b,t} \sim i.i.d.N(0, \sigma_{\varepsilon b}^2)$ . Following Zhang (2019), we assume that in the event of a default the household incurs an indirect cost in the form of a bad repayment record that results in a low credit score. To capture the cost associated with credit default, we introduce  $\vartheta_b \in [0, 1]$ , which is a fraction of the wealth transfer that the household must use to pay for the cost associated with the credit default.

The household also faces the following borrowing constraint that limits the amount of borrowing to a fraction  $m_b$  of the expected value of housing:<sup>9</sup>

$$L_{b,t} \leq m_b E_t \left( \frac{q_{t+1}}{R_{b,t}} H_{b,t} \pi_{t+1} \right) \gamma_{b,t}. \quad (4.10)$$

$m_b \in (0, 1)$  is the LTV ratio for the impatient household. The term  $\gamma_{b,t}$  is an exogenous shock to the borrowing capacity of the household in line with Mendicino and Punzi (2014) and Iacoviello (2015). This shock evolves as follows:

$$\log \gamma_{b,t} = \rho_{\gamma b} \log \gamma_{b,t-1} + \xi_{\gamma b,t}, \quad (4.11)$$

where  $\rho_{\gamma b}$  is a parameter governing the persistence of the shock.  $\xi_{\gamma b,t} \sim i.i.d.N(0, \sigma_{\gamma b}^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_{\gamma b}^2$ . The shock captures exogenous changes in the bank's (lender's) confidence or optimism in the credit market which changes the bank's valuation of the collateral assets (housing).<sup>10</sup>

<sup>8</sup>This is in contrast to Iacoviello (2015), in which the author introduces a redistribution shock (that transfers wealth from the bank to the borrowers, analogous to a fraction of NPLs) in an ad hoc manner and assumes that it is exogenous.

<sup>9</sup>The assumption that  $\beta_b < \beta_s$  ensures that the borrowing constraint binds in the neighborhood of the steady state. As is common in the literature, we also assume that the magnitude of uncertainty in the economy (the size of the shocks) is too small to induce agents to borrow less than the credit limit (see for e.g., Iacoviello, 2005).

<sup>10</sup>See also Ngo (2015) and Funke et al. (2018).

Let  $U_{Cb,t} = \frac{1-\eta_b}{C_{b,t}-\eta_b C_{b,t-1}}$  be the marginal utility of consumption and  $\lambda_{b,t}$  be the multiplier on the borrowing constraint. The first order conditions which define the impatient household's problem are as follows:

$$1 - \frac{\lambda_{b,t}}{U_{Cb,t}} = \beta_b E_t \left( \frac{U_{Cb,t+1}}{U_{Cb,t}} \frac{R_{b,t} (1 - \zeta_{b,t+1} (1 - \vartheta_b))}{\pi_{t+1}} \right), \quad (4.12)$$

$$q_t = j \frac{A_{j,t}}{H_{b,t} U_{Cb,t}} + \beta_b E_t \left( \frac{U_{Cb,t+1}}{U_{Cb,t}} q_{t+1} \right) + m_b E_t \left( \frac{\lambda_{b,t}}{U_{Cb,t}} \frac{\pi_{t+1}}{R_{b,t}} q_{t+1} \right) \gamma_{b,t}, \quad (4.13)$$

$$w_{b,t} = \frac{\tau}{(1 - N_{b,t}) U_{Cb,t}}. \quad (4.14)$$

Eq. (4.12) describes the household's demand for bank loans. Eq. (4.13) is the household's optimal demand for housing. It equates the current price of housing to its marginal benefit, which is given by the marginal utility of consuming one extra unit of housing, its expected resale value and its ability to serve as collateral. Eq. (4.14) is the labour supply condition for the household.

### 4.2.3 Entrepreneurs

The representative entrepreneur maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1 - \eta_e) \log(C_{e,t} - \eta_e C_{e,t-1}), \quad (4.15)$$

where  $\beta_e$  is the entrepreneur's subjective discount factor such that  $\beta_e < \beta_s$ .  $C_{e,t}$  is the entrepreneur's consumption. Since the entrepreneur is the owner of production firms,  $C_{e,t}$  can be regarded as profits or dividends. Therefore,  $\eta_e C_{e,t-1}$  captures some form of dividend smoothing in line with Liu et al. (2013). Liu et al. (2013) point out that this form of dividend smoothing is essential for the model to adequately explain the dynamics between asset prices and real variables.

In each period, the representative entrepreneur,  $z$ , produces intermediate goods,  $Y_t(z)$ , using the patient and impatient households' labour supply,  $N_{s,t}(z)$  and  $N_{b,t}(z)$ , and housing,  $H_{e,t}(z)$ , as inputs. The entrepreneur then sells these goods to the retailers at a wholesale price  $P_{w,t}(z)$ . Production technology is given by a constant return to scale Cobb-Douglas production function:

$$Y_t(z) = Z_t H_{e,t-1}(z)^\nu [N_{s,t}(z)^{1-\sigma} N_{b,t}(z)^\sigma]^{1-\nu}, \quad (4.16)$$

where  $\nu \in (0, 1)$  is the elasticity of output with respect to housing and,  $\sigma \in (0, 1)$  is the relative share of the impatient household's labour supply in the production (share of the impatient household's labour income). The technology shock,  $Z_t$ , evolves according to the following law of motion:

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}, \quad (4.17)$$

where  $\rho_z$  is the persistence of the shock.  $\xi_{z,t} \sim i.i.d.N(0, \sigma_z^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_z^2$ .

The entrepreneur's budget constraint is given by:<sup>11</sup>

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + \frac{R_{e,t}}{\pi_t}(1 - \zeta_{e,t}(1 - \vartheta_e))L_{e,t-1} + w_{s,t}N_{s,t} + w_{b,t}N_{b,t} = \frac{1}{X_t}Y_t + L_{e,t}, \quad (4.18)$$

where  $X_t = P_t/P_{w,t}$  is the markup or the inverse of the marginal cost.  $L_{e,t}$  is bank loans to the entrepreneur, which accrue a real gross interest rate,  $R_{e,t}/\pi_t$ .  $\zeta_{e,t}$  is a fraction of entrepreneur NPLs, which captures partial defaults by the entrepreneur on the loan contract, as in the case of the impatient household.  $\vartheta_e$  is a fraction of the wealth transfer that the entrepreneur must pay for the costs related to the default, similar to that of the impatient household. The fraction of entrepreneur NPLs evolves as follows:

$$\zeta_{e,t} = \zeta_e(\zeta_{e,t-1})^{\rho_{\varepsilon e}}(Y_t/Y_{t-1})^{-\chi_{\zeta e}}e^{\xi_{\varepsilon e,t}}, \quad (4.19)$$

where  $\zeta_e$  is the steady-state value of entrepreneur NPLs and  $\chi_{\zeta e} > 0$  measures the elasticity of the NPLs with respect to output growth.  $\rho_{\varepsilon e}$  measures the persistence of the NPLs.  $\xi_{\varepsilon e,t}$  is an independent and identically distributed (i.i.d.) NPL shock with mean zero and variance  $\sigma_{\varepsilon e}^2$ . That is,  $\xi_{\varepsilon e,t} \sim i.i.d.N(0, \sigma_{\varepsilon e}^2)$ .

The entrepreneur also faces a borrowing constraint, which limits the total amount of borrowing to the expected value of housing. That is:

$$L_{e,t} \leq m_e E_t \left( \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \pi_{t+1} \right) \gamma_{e,t}, \quad (4.20)$$

where  $m_{e,t}$  is the LTV ratio for the entrepreneur. The term  $\gamma_{e,t}$  is an exogenous shock to the borrowing capacity of the entrepreneur which evolves as follows:

$$\log \gamma_{e,t} = \rho_{\gamma e} \log \gamma_{e,t-1} + \xi_{\gamma e,t}, \quad (4.21)$$

where  $\rho_{\gamma e}$  is the persistence of the shock.  $\xi_{\gamma e,t} \sim i.i.d.N(0, \sigma_{\gamma e}^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_{\gamma e}^2$ .

<sup>11</sup>Note that symmetry across entrepreneurs allows us to write the budget constraint without the index  $z$ .

Let  $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$  be the marginal utility of consumption and  $\lambda_{e,t}$  be the multiplier on the borrowing constraint (4.20). The first order conditions which define the entrepreneur's problem are as follows:

$$1 - \frac{\lambda_{e,t}}{U_{Ce,t}} = \beta_e E_t \left( \frac{U_{Ce,t+1}}{U_{Ce,t}} \frac{R_{e,t+1} \left( 1 - \zeta_{e,t+1} (1 - \vartheta_e) \right)}{\pi_{t+1}} \right), \quad (4.22)$$

$$q_t = \beta_e E_t \left[ \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \frac{\nu}{X_{t+1}} \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) \right] + m_e E_t \left( \frac{\lambda_{e,t}}{U_{Ce,t}} \frac{\pi_{t+1}}{R_{e,t+1}} q_{t+1} \right) \gamma_{e,t}, \quad (4.23)$$

$$w_{s,t} = (1 - \sigma)(1 - \nu) \frac{1}{X_t} \frac{Y_t}{N_{s,t}}, \quad (4.24)$$

$$w_{b,t} = \sigma(1 - \nu) \frac{1}{X_t} \frac{Y_t}{N_{b,t}}. \quad (4.25)$$

Eq. (4.22) is the optimal demand for bank loans. Eq. (4.23) represents the entrepreneur's demand for housing. It equates the current price of housing to its expected resale value plus the pay-off from holding this asset for one period (given by its marginal productivity and its ability to serve as collateral asset). Eqs. (4.24) and (4.25) are the optimal demand for patient and impatient households' labour, respectively.

#### 4.2.4 Retailers

There is a continuum of monopolistically competitive retailers, indexed by  $k \in [0, 1]$ . They buy undifferentiated intermediate goods,  $Y_t(z)$ , from entrepreneurs at the price,  $P_{w,t}$ . They then brand these goods and transform them into differentiated goods,  $Y_t(k)$ , at no costs and sell them at the price,  $P_t(k)$ . The final good,  $Y_t$ , is a constant elasticity of substitution (CES) composite of the continuum of differentiated goods:

$$Y_t = \left[ \int_0^1 Y_t(k)^{(\epsilon-1)/\epsilon} dk \right]^{\epsilon/(\epsilon-1)}, \quad (4.26)$$

where  $\epsilon > 1$  is the intratemporal elasticity of substitution across goods. The profit maximisation yields the demand for good  $k$  as:<sup>12</sup>

$$Y_t(k) = \left( \frac{P_t(k)}{P_t} \right)^{-\epsilon} Y_t. \quad (4.27)$$

<sup>12</sup>The profit function is given by:  $P_t Y_t - \int_0^1 P_t(k) Y_t(k)$ .

The price index is then given by:

$$P_t = \left[ \int_0^1 P_t(k)^{1-\epsilon} dk \right]^{1/(\epsilon-1)}. \quad (4.28)$$

To motivate for price rigidity, following Calvo (1983), we assume that the retailers operate in a monopolistically competitive environment and set prices in a staggered manner. In each period, each retailer gets the opportunity to adjust prices to a new level with a probability of  $(1 - \theta)$ . Furthermore, we introduce price inertia by assuming that prices of the retailers who do not receive the Calvo signal are partially indexed to the last period's inflation rate as in Smets and Wouters (2003). Let  $\tilde{P}_t(k)$  be the reset price and the corresponding demand be  $\tilde{Y}_{t+i}(k) = (\tilde{P}_t(k)/P_{t+i})^{-\epsilon} Y_{t+i}$ . Then, the optimal reset price solves:

$$\sum_{i=0}^{\infty} \theta^i \left[ \Lambda_{t,i} \left( \frac{\tilde{P}_t(k)}{P_{t+i}} - \frac{X}{X_{t+i}} \right) \tilde{Y}_{t+i}(k) \right] = 0, \quad (4.29)$$

where,  $\Lambda_{t,i} = \beta^i (U_{Cs,t+i}/U_{Cs,t})$  is the patient household's stochastic discount factor and  $X_t$  is the markup, which at the steady state is  $X = \epsilon/(\epsilon - 1)$ .

The aggregate price level is given by:

$$(P_t)^{1/(1-\epsilon)} = \theta \left[ P_{t-1} \left( \frac{P_{t-1}}{P_{t-2}} \right)^{\iota_p} \right]^{1-\epsilon} + (1 - \theta) (\tilde{P}_t)^{1-\epsilon}, \quad (4.30)$$

where  $\iota_p$  is the degree of indexation to past inflation. Combining Eq. (4.29) and Eq. (4.30) and log-linearising yields a forward-looking New Keynesian Phillips curve to which we add a normally distributed cost-push shock as follows:

$$\hat{\pi}_t = \frac{\iota_p}{1 + \iota_p \beta_s} \hat{\pi}_{t-1} + \frac{\beta_s}{1 + \iota_p \beta_s} E_t \hat{\pi}_{t+1} - \frac{(1 - \theta)(1 - \beta_s \theta)}{(1 + \iota_p \beta_s) \theta} \hat{x}_t + \xi_{\pi,t}, \quad (4.31)$$

where  $\xi_{\pi,t}$  is an independent and identically distributed (i.i.d) cost-push shock with mean zero and variance  $\sigma_{\pi}^2$ . That is,  $\xi_{\pi,t} \sim i.i.d.N(0, \sigma_{\pi}^2)$ .<sup>13</sup>

## 4.2.5 The bank

The main role of the bank is to mediate funds between savers (patient households) and borrowers (impatient households and entrepreneurs). The bank chooses consumption ( $C_{f,t}$ ) to maximise the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1 - \eta_f) \log(C_{f,t} - \eta_f C_{f,t-1}), \quad (4.32)$$

<sup>13</sup>Variables with a hat denote percent deviations from the steady state.

where  $\beta_f$  is the bank's subjective discount factor, such that  $\beta_f < \beta_s$ . Note that  $C_{f,t}$  can be interpreted as dividends or profits generated by the bank, which are assumed to be fully consumed by the bank.  $\eta_f C_{f,t-1}$  represents some form of dividend smoothing. The bank's budget constraint is given by:

$$C_{f,t} + \frac{R_{t-1}}{\pi_t} D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + \frac{R_{b,t-1}}{\pi_t} (1 - \zeta_{b,t}) L_{b,t-1} + \frac{R_{e,t}}{\pi_t} (1 - \zeta_{e,t}) L_{e,t-1}, \quad (4.33)$$

where  $D_t$  is the patient household's deposits.  $L_{b,t}$  and  $L_{e,t}$  are bank loans to impatient households and entrepreneurs, respectively.  $AC_{bf,t} = \frac{\phi_{bf}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_b}$  and  $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$  are quadratic loan portfolio adjustment costs associated with household and entrepreneur loans, respectively.  $\zeta_{b,t}$  and  $\zeta_{e,t}$  are household and entrepreneur NPLs, respectively. For the bank, these represent loan losses that the bank incurs when the impatient households and the entrepreneurs default on their loan contracts.

In addition to the budget constraint, the bank faces a capital requirement constraint. In line with the Basel capital regulations, the bank capital requirement constraint states that the bank must finance a certain fraction ( $\kappa$ ) of new loans by equity (retained earnings in this model). In other words, the regulation requires the bank to hold a capital-to-assets ratio greater than or equal to some predetermined ratio ( $\kappa$ ). Let bank capital be  $BK_t = L_t - E_t \zeta_{t+1} - D_t$ .<sup>14</sup> The capital requirement constraint is given by:

$$\frac{L_t - E_t \zeta_{t+1} - D_t}{w_b \left( L_{b,t} - E_t \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} \right) + w_e \left( L_{e,t} - E_t \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right)} \geq \kappa, \quad (4.34)$$

where  $\kappa \in (0, 1)$  is the capital requirement ratio (CRR) and  $L_t = L_{b,t} + L_{e,t}$  is total loans.  $E_t \zeta_{t+1}$  represents the allowance for the expected loan losses.  $w_b$  and  $w_e$  are risk weights on household and entrepreneur loans, respectively. These parameters capture different degrees of risk associated with household and entrepreneur loans. The capital requirement constraint (4.34) can be rewritten as a borrowing constraint, as follows:

$$D_t \leq (1 - w_b \kappa) \left( L_{b,t} - E_t \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} \right) + (1 - w_e \kappa) \left( L_{e,t} - E_t \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right). \quad (4.35)$$

Eq. (4.35) states that the amount of deposits that the bank can take from the patient household cannot exceed a weighted sum of the bank's net assets (loans net of the expected loan

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<sup>14</sup>  $E_t \zeta_{t+1} = E_t \left( \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} + \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right)$  is the expected loan losses on the bank's loan portfolio and  $L_t - E_t \zeta_{t+1}$  is net loans.

losses), where the weights attached to the household loans and entrepreneur loans are  $(1 - w_b\kappa)$  and  $(1 - w_e\kappa)$ , respectively. This constraint limits the extent to which the bank can take on leverage. The condition that  $\beta_f < \beta_s$  ensures that the constraint (4.35) is always binding at the steady state. In the absence of this assumption, the bank may find that it is optimal to postpone current consumption indefinitely and accumulate capital to the point where the capital requirement constraint does not have force.

Let  $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t}-\eta_f C_{f,t-1}}$  be the marginal utility of consumption and  $\lambda_{f,t}$  be the multiplier on the bank's borrowing constraint (4.35). The first order conditions which define the bank's problem are as follows:

$$\beta_f E_t \left( \frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_t}{\pi_{t+1}} \right) = 1 - \frac{\lambda_{f,t}}{U_{Cf,t}}, \quad (4.36)$$

$$\beta_f E_t \left( \frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_{b,t}}{\pi_{t+1}} (1 - \zeta_{b,t+1}) \right) = 1 - E_t \left[ (1 - w_b\kappa) \frac{\lambda_{f,t}}{U_{Cf,t}} \left( 1 - \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} \right) \right] + \frac{\phi_{bf}}{L_b} (L_{b,t} - L_{b,t-1}), \quad (4.37)$$

$$\beta_f E_t \left( \frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_{e,t+1}}{\pi_{t+1}} (1 - \zeta_{e,t+1}) \right) = 1 - E_t \left[ (1 - w_e\kappa) \frac{\lambda_{f,t}}{U_{Cf,t}} \left( 1 - \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} \right) \right] + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}), \quad (4.38)$$

Eq. (4.36) describes the bank's demand for deposits. Eqs. (4.37) and (4.38) are the bank's optimal conditions for supplying loans to households and entrepreneurs, respectively.

#### 4.2.6 Monetary policy

Monetary policy is exemplified by a standard Taylor-type rule with interest rate smoothing as follows:<sup>15</sup>

$$R_t = R \left( \frac{R_{t-1}}{R} \right)^{\phi_r} \left[ \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi} \left( \frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \right]^{(1-\phi_r)} e^{\xi_{r,t}}, \quad (4.39)$$

where  $\phi_r$  is the degree of interest rate smoothing,  $\phi_\pi$  and  $\phi_y$  measure the response of the policy rate to inflation and output growth, respectively.  $R$  and  $\pi$  are steady-state values of  $R_t$  and  $\pi_t$ , respectively.  $\xi_{r,t}$  is an i.i.d. monetary policy shock with mean zero and variance  $\sigma_r^2$ . That is,  $\xi_{r,t} \sim i.i.d.N(0, \sigma_r^2)$ .

<sup>15</sup>This is consistent with monetary policy under an inflation-targeting regime such as the one the South African Reserve Bank has been following since 2000.

### 4.2.7 Market clearing conditions and equilibrium

The aggregate resource constraint is obtained by adding together the budget constraints of all agents in the economy (households, entrepreneurs and the bank), including the profit functions of the retailers:

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_t, \quad (4.40)$$

where  $Adj_t = AC_{bf,t} + AC_{ef,t}$ .

Total consumption is given by:

$$C_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t}. \quad (4.41)$$

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \quad (4.42)$$

In the credit market, the total supply of loans equals the demand by impatient households and entrepreneurs:

$$L_t = L_{b,t} + L_{e,t}. \quad (4.43)$$

## 4.3 Estimation

We estimate the model for the South African economy using Bayesian techniques as discussed in An and Schorfheide (2007).<sup>16</sup> In what follows, we briefly discuss the observable variables being used for estimation, the calibrated parameters, and the prior and posterior distribution of the parameters.

### 4.3.1 Data

We use quarterly data over the sample period 2000Q1–2016Q4, which coincides with the inflation-targeting monetary policy regime in South Africa. The model allows for a total of 8 shocks. In line with the standard practice in the DSGE literature, we have as many shocks as the number of observable variables in the data set. The observable variables are real gross domestic product (GDP) per capita, real household credit per capita, real corporate credit per capita, inflation rate, short-term nominal interest rate, real house prices, ratio of household NPLs to

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<sup>16</sup>We use Dynare (version 4.5.7) to estimate the model.



total household loans and ratio of corporate NPLs to total corporate loans.<sup>17</sup> Fig. 4.1 plots the transformed observable variables being used for estimation. Before proceeding with the estimation, we detrend the logarithm of real variables by taking the first-difference of each variable and subtracting the corresponding sample mean. Inflation, interest rate, ratios of household NPLs and corporate NPLs are demeaned. Most of the data are obtained from the South African Reserve Bank database. House price data are obtained from ABSA bank (one of the leading banks in South Africa), interest rate data from the International Monetary Fund's International Financial Statistics database, and population data from World Bank database.

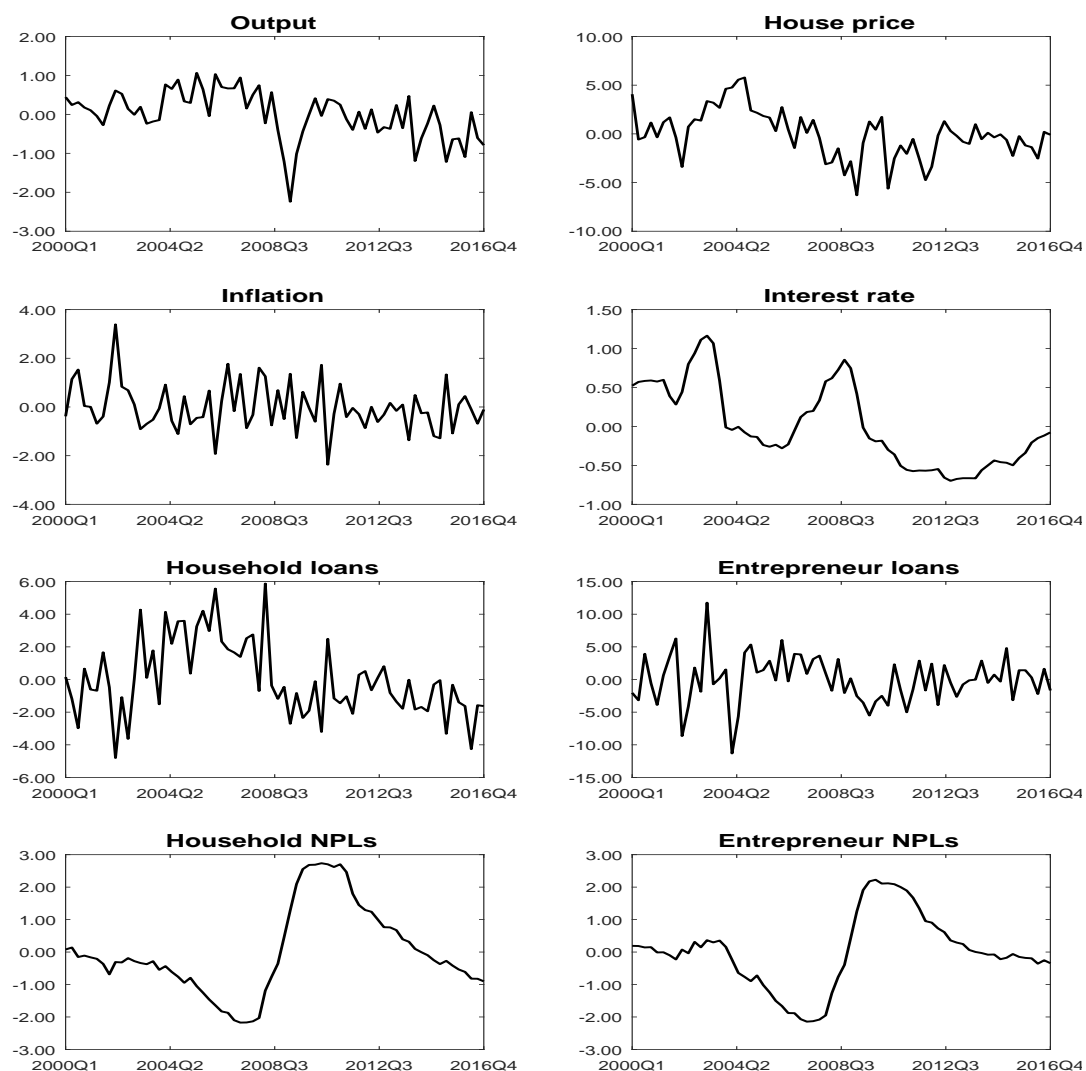


Figure 4.1: Observable variables. Note: Output, house prices, household loans and entrepreneur loans are demeaned percentage growth rates. Inflation rate, interest rate, ratios of household and entrepreneur (corporate) NPLs are in percentage deviations from their respective sample means.

<sup>17</sup>In Appendix C.2, we present a more detailed description of the data.

### 4.3.2 Calibration

As is standard in Bayesian estimation of DSGE models, we calibrate a subset of parameters for which the data set being used for estimation cannot provide sufficient information. Some of these parameters are calibrated based on the data and steady state conditions of the model, while others are borrowed from the literature. These parameters are presented in Table 4.1.

The discount factor for patient households is set at  $\beta_s = 0.995$ , for impatient households at  $\beta_b = 0.97$  and for entrepreneurs at  $\beta_e = 0.96$ . The choice of these values ensures that both impatient households' and entrepreneurs' borrowing constraints are binding in the neighbourhood of steady state. The steady-state value of the gross inflation rate is set at  $\pi = 1.016$ , which implies an annual inflation rate of 6.4% in the steady state, which is fairly in line with the data over the sample period. Together with patient households' discount factor, this value implies a steady-state nominal interest rate of 8.5% per annum, which is slightly higher than the sample mean from the data for the period 2000Q1–2016Q4.

Table 4.1: Calibrated parameters.

Parameter	Symbol	Value	Parameter	Symbol	Value
Discount factor (patient HH)	$\beta_s$	0.995	NPL persistence (impatient HH)	$\rho_{\varepsilon b}$	0.7
Discount factor (impatient HH)	$\beta_b$	0.97	NPL persistence (Entrep.)	$\rho_{\varepsilon e}$	0.7
Discount factor (Entrep.)	$\beta_f$	0.96	Steady-state capital requirement ratio	$\kappa$	0.13
Discount factor (Bank)	$\beta_b$	0.95	Steady-state LTV ratio (impatient HH)	$m_b$	0.80
Housing preference	$j$	0.12	Steady-state LTV ratio (Entrep.)	$m_e$	0.60
Labor supply parameter	$\tau$	2	Steady-state ratio of HH NPLs	$\zeta_b$	0.04
Housing share in production	$\nu$	0.1	Steady-state ratio of Entrep. NPLs	$\zeta_e$	0.034
Risk weight (impatient HH loans)	$w_b$	1	Steady-state inflation	$\pi$	1.016
Risk weight (Entrep. loans)	$w_e$	1	Steady-state gross markup	$X$	1.10

Note: HH, Entrep and NPL stand for household, entrepreneur and non-performing loan.

The weight on leisure in the households' utility function is set at  $\tau = 2$ . This value implies that households devote approximately one third of their time to work in line with the literature. The share of housing in production is set at  $\nu = 0.1$  in the ballpark of the values widely used in the literature for emerging market economies (e.g., Iacoviello and Minetti, 2006; Minetti and Peng, 2018). The housing weight in the utility functions is calibrated at  $j = 0.12$ . The choice of these values implies that in the steady state the share of households' housing wealth (residential housing wealth) to total housing wealth is 0.80 while the remaining share of 0.20

is entrepreneurs' housing wealth (commercial housing wealth). These values are fairly in line with the South African data on housing wealth.<sup>18</sup>

Leverage ratios for impatient households and entrepreneurs are set based on the South African credit market data over the sample period. The steady-state LTV ratio for impatient households is set at  $m_b = 0.8$ . This value is fairly consistent with the minimum down-payment that South African banks require for providing home loans. For the entrepreneurs, the steady-state LTV ratio is set at  $m_e = 0.6$ . Both values are well within the observed maximum LTV ratios for a first-time mortgage buyer typically found in emerging and developing economies (see, e.g., IMF, 2011). These values pin down the steady-state ratio of household loans to output at 0.35 and of entrepreneur loans to output at 0.34, consistent with the South African credit market data.

The steady-state capital requirement ratio is set at  $\kappa = 0.13$  to match the historical average observed in the South African banking data. The risk weights assigned to household and entrepreneur loans are both set at  $w_b = w_e = 1$ . The discount factor for banks is set at  $\beta_f = 0.95$ . This value is lower than the patient households' discount factor ( $\beta_s$ ) and guarantees that the banks' borrowing constraint (4.35) is binding in the neighbourhood of the steady state. The steady-state ratios of household and entrepreneur NPLs are set at  $\zeta_b = 0.04$  and  $\zeta_e = 0.034$ , respectively, matching their historical average values. Together with impatient households' and entrepreneurs' discount factors, these values imply the spread of more than 500 basis points between the effective lending rates (risk-adjusted lending rates) and deposit (policy) rate, which is broadly in line with the South African interest rate data.<sup>19</sup>

We set the steady-state gross markup at  $X = 1.10$ , which is in the ballpark of values widely used in the literature.<sup>20</sup> This implies a steady-state markup of 10% in the retail sector. The parameters measuring the persistence of household and entrepreneur NPLs are set at  $\rho_{\epsilon b} = \rho_{\epsilon e} = 0.7$ .

<sup>18</sup>The 2016 Property Sector Charter Council's report suggests that residential housing wealth constitutes approximately 80% of the total South African housing wealth while the remainder is commercial housing wealth. Source: <http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html>.

<sup>19</sup>The risk-adjusted lending rate or effective lending rate is approximated by the average of a sum of lending rates, as reported by the South Africa Reserve Bank, and ratios of NPLs.

<sup>20</sup>For the case of South Africa, see for example Liu and Seeiso (2012) and Gupta and Sun (2018).

### 4.3.3 Prior distributions

Tables 4.2 and 4.3 report prior distributions, means and standard deviations of the remaining set of parameters to be estimated. The choice of these priors is guided by the DSGE literature, particularly in the context of South Africa.

The degree of habit persistence is assumed to follow a beta distribution with a mean of 0.5 and a standard deviation of 0.05. The parameter for the impatient household's labour income share is assumed to follow a beta distribution with a mean of 0.3 and a standard deviation of 0.02. These priors are based on Iacoviello (2015) and Gupta and Sun (2018). The priors for the parameters of the monetary policy rule are set as follows. The interest rate smoothing parameter is assumed to follow a beta distribution with a mean of 0.7 and a standard deviation of 0.05. The coefficients on inflation and output growth are assumed to follow a gamma and a normal distribution with means of 1.5 and 0.5, respectively, and a standard deviation of 0.05. These values are in line with Steinbach et al. (2009), Alpanda et al. (2010), Liu (2013) and du Plessis et al. (2014).

The elasticities of household and entrepreneur NPLs with respect to output are assumed to follow a beta distribution with a mean of 0.5 and a standard deviation of 0.1. This is in line with Steinbach et al. (2014). The prior mean for these parameters is also consistent with the estimated elasticity of NPLs with respect to output growth across major developing economies, including South Africa, in Glen and Mondragón-Vélez (2011). The parameters governing household and entrepreneur default costs ( $\vartheta_b$  and  $\vartheta_e$ ) follow a beta distribution with a mean of 0.5 and a standard deviation of 0.2, in line with Zhang (2019). The loan portfolio adjustment cost parameters are assumed to follow a gamma distribution with a mean of 0.25 and a standard deviation of 0.125, in line with Iacoviello (2015).

The persistence of all structural shocks is assumed to follow a beta distribution with a mean of 0.8 and a standard deviation of 0.1 in line with the literature (e.g., Steinbach et al., 2009; Alpanda et al., 2010; Gupta and Sun, 2018). The standard deviation of the shocks is assumed to follow an inverse gamma distribution with a mean of 0.1 and standard deviation of 0.25.

Table 4.2: Prior and posterior distributions of the structural parameters.

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev.	5 %	Mean	95 %
Habit persistence	$\eta$	beta	0.50	0.05	0.5257	0.5609	0.5959
Impatient HH income share	$\sigma$	beta	0.30	0.02	0.2250	0.2412	0.2581
Calvo parameter	$\theta$	beta	0.65	0.02	0.4693	0.5057	0.5435
Price indexation	$\iota_\pi$	beta	0.50	0.05	0.3030	0.3884	0.4787
Interest rate smoothing	$\phi_r$	beta	0.70	0.05	0.4085	0.4688	0.5266
Taylor coefficient on inflation	$\phi_\pi$	gamma	1.70	0.05	1.6071	1.7016	1.7965
Taylor coefficient on output	$\phi_y$	normal	0.50	0.05	0.4752	0.5589	0.6437
Elasticity of HH NPLs w.r.t output	$\chi_{\zeta b}$	gamma	0.50	0.10	0.3010	0.4916	0.6821
Elasticity of Entrep. NPLs w.r.t output	$\chi_{\zeta e}$	gamma	0.50	0.10	0.2749	0.4468	0.6228
HH default cost parameter	$\vartheta_b$	beta	0.50	0.10	0.5954	0.7042	0.8108
Entrep. default cost parameter	$\vartheta_e$	beta	0.50	0.10	0.0640	0.1287	0.2024
Impatient HH loan adj. cost	$\phi_{bf}$	gamma	0.25	0.125	0.9309	1.0396	1.1500
Entrep. loan adj. cost	$\phi_{ef}$	gamma	0.25	0.125	0.0061	0.0281	0.0542

Notes: The posterior density is constructed by simulation using the Random-Walk Metropolis algorithm (two chains with 250,000 draws each). HH, Entrep. and NPL stand for household, entrepreneur and non-performing loan.

### 4.3.4 Posterior estimates

The last three columns of Tables 4.2 and 4.3 show the posterior mean and the 5 and 95 percentiles of the posterior distributions of the estimated parameters.<sup>21</sup> The habit persistence parameter is estimated at 0.56 and the impatient households' labour income share parameter at 0.24. These values are fairly in line with the estimated values in Iacoviello (2015) and Gupta and Sun (2018). The Calvo parameter, which measures the degree of price stickiness, is estimated at 0.51. This implies that entrepreneurs adjust prices approximately every 2 quarters. The results also imply a moderate degree of price indexation to the past inflation, at the estimated value of 0.39, for entrepreneurs who do not adjust prices every quarter.

Turning to the parameters governing the monetary policy rule, we find that the parameters for the response of the policy rate to inflation and output growth (Taylor coefficients) are  $\phi_\pi = 1.70$  and  $\phi_y = 0.56$ , respectively. The results also suggest that there is a modest degree of interest rate smoothing, estimated at  $\phi_\pi = 0.47$ . These values are fairly in line with the Taylor principle and the South African literature (see for e.g., Steinbach et al., 2009; Liu, 2013). The elasticities of household and entrepreneur NPLs with respect to output growth are 0.49 and 0.45,

<sup>21</sup>We present the prior and posterior marginal densities of the structural parameters and multivariate convergence diagnostics plots in appendices C.3 and C.4. Results for the impulse response functions (IRFs) analysis and the historical shock decomposition analysis are reported in appendices C.5 and C.6.

Table 4.3: Prior and posterior distributions of the shocks.

Parameter	Prior distribution				Posterior distribution		
		Density	Mean	St.dev.	5 %	Mean	95 %
<b>AR(1) coefficients</b>							
Housing demand shock	$\rho_j$	beta	0.80	0.10	0.9896	0.9929	0.9959
Technology shock	$\rho_z$	beta	0.80	0.10	0.9864	0.9924	0.9977
HH LTV shock	$\rho_{\gamma b}$	beta	0.80	0.10	0.8924	0.9342	0.9748
Entrep. LTV shock	$\rho_{\gamma e}$	beta	0.80	0.10	0.9252	0.9483	0.9695
<b>Standard deviations</b>							
Housing demand shock	$\sigma_j$	invg	0.10	0.25	0.0282	0.0367	0.0456
Technology shock	$\sigma_z$	invg	0.10	0.25	0.0099	0.0108	0.0118
HH LTV shock	$\sigma_{\gamma b}$	invg	0.10	0.25	0.0174	0.0197	0.0220
Entrep. LTV shock	$\sigma_{\gamma e}$	invg	0.10	0.25	0.0165	0.0177	0.0189
Monetary policy shock	$\sigma_r$	invg	0.10	0.25	0.0078	0.0088	0.0098
Cost-push shock	$\sigma_\pi$	invg	0.10	0.25	0.0120	0.0138	0.0155
HH NPL shock	$\sigma_{\varepsilon b}$	invg	0.10	0.25	0.1038	0.1172	0.1307
Entrep. NPL shock	$\sigma_{\varepsilon e}$	invg	0.10	0.25	0.1227	0.1434	0.1656

Notes: The posterior density is constructed by simulation using the Random-Walk Metropolis algorithm (two chains with 250,000 draws each). HH, Entrep. and NPL stand for household, entrepreneur and non-performing loan. AR stands for autoregressive.

respectively. These values are fairly in line with the estimated value in Glen and Mondragón-Vélez (2011) for emerging markets. The default cost parameter for impatient households is 0.70 and for entrepreneurs 0.13. This implies that, in the event of loan default, impatient households use approximately 70% of transfers of wealth from the bank to pay the costs associated with default, whereas entrepreneurs use only 13% of transfers of wealth to pay the default costs.

## 4.4 Business cycle properties

In this section we assess the performance of the estimated model. Specifically, we evaluate how well the model conforms to the actual data in terms of standard deviation and correlation of key variables with output.

Table 4.4 shows that the estimated model does a fairly good job of matching the data moments. The model reproduces the standard deviations of house prices, inflation and the policy rate fairly in line with the data. It also does a reasonably good job of reproducing the standard deviations of output, household loans and corporate loans, but somewhat overstates them. Importantly, the model does a good job in reproducing the fact that entrepreneur loans are more

Table 4.4: Business cycle properties.

Variable	Standard deviation		Correlation with output	
	Data	Model	Data	Model
Output	0.61	0.96	1.00	1.00
House prices	2.44	2.33	0.42	0.72
Inflation	0.96	0.99	-0.03	-0.50
Policy rate	0.51	0.63	0.10	-0.70
Household loans	2.28	3.12	0.46	0.55
Entrepreneur loans	3.60	6.41	0.09	0.54

Notes: We do not report the business cycle properties for household and entrepreneur NPLs because we have used proxies for these two variables.

volatile than household loans, and also the fact that entrepreneur loans, household loans, house prices and inflation are more volatile than output, while the policy rate is less volatile than output. Turning to the correlation of the variables with output, the results show that the model reproduces a strong correlation of output with house prices and household loans, consistent with the data. Although the model overestimates the correlation of output with corporate loans and inflation, it does a good job of predicting a countercyclical (negative correlation with) inflation and a procyclical (positive correlation with) corporate loans. However, the model fails to reproduce the positive correlation of output with the policy rate. In general, the estimated model does a reasonably good job of matching the stylised facts observed in the South African data over the period 2000Q1–2016Q4.

## 4.5 Optimal monetary and macroprudential policy

In this section we investigate the optimal design and effectiveness of a simultaneous deployment of monetary and macroprudential policies in promoting macroeconomic and financial stability. To conduct this analysis, we set the model parameters at their posterior means obtained from the estimation and use the optimal simple rule (OSR) optimisation routine in Dynare to derive the optimal monetary and macroprudential policy parameters. In what follows, we first describe the loss function and policy regimes to be used for the optimal simple rule analysis and then report the results of the OSR analysis.

### 4.5.1 Policy loss function

To find the optimal policy, following Angelini et al. (2014) and Agénor et al. (2018), we assume the central bank minimises the quadratic welfare loss function in terms of a weighted sum of the volatilities of inflation, output, credit-to-output ratio and house prices as follows:

$$\mathcal{L} = \sigma_{\pi}^2 + \lambda_y \sigma_y^2 + \lambda_{l/y} \sigma_{l/y}^2 + \lambda_q \sigma_q^2, \quad (4.44)$$

where  $\sigma_{\pi}^2$ ,  $\sigma_y^2$ ,  $\sigma_{l/y}^2$  and  $\sigma_q^2$  are the volatilities of inflation, output, credit-to-output ratio and house prices, respectively. Parameters  $\lambda_y, \lambda_{l/y}, \lambda_q \geq 0$  are the relative weights of output, credit-to-output ratio and house prices in the loss function, respectively. To simplify our analysis, we conduct policy experiments with the weights of  $\lambda_y = 0.5$ ,  $\lambda_{l/y} = 0.5$  and  $\lambda_q = 0.05$  in the loss function.<sup>22</sup> We assign a lower weight to output than to inflation, to reflect South Africa's inflation-targeting monetary policy regime over the sample period. We assign a lower weight to the volatility of house prices than to the volatility of credit-to-output ratio, based on the empirical evidence that fluctuations in credit-to-output ratio are more important than fluctuations in asset prices in predicting financial distress (Agénor and Pereira da Silva, 2017; Agénor et al., 2018). We only consider the case where there is a single policymaker (a central bank) that pursues both macroeconomic and financial stability objectives using the two policy instruments – the policy rate and the capital requirement ratio. That is, we assume that monetary and macroeconomic policies are conducted under full coordination.

### 4.5.2 Policy regimes

To study the effectiveness of a joint implementation of monetary and macroprudential policies, we assess two alternative policy regimes (II and III) against a benchmark regime (I). The benchmark regime is described by the standard Taylor rule (4.39), and a constant capital requirement ratio without the macroprudential policy rule, i.e. the countercyclical capital requirement (CcCR).

Regime II is a combination of the standard Taylor rule (4.39) and the CcCR which relates the capital requirement ratio to the credit-to-output gap as follows:

$$\kappa_t = \kappa \left( \frac{L_t/Y_t}{L/Y} \right)^{\chi_l}, \quad (4.45)$$

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<sup>22</sup>We also perform additional experiments with different weights on the volatilities of output and credit-to-output ratio in the ranges  $\lambda_y = [0.5, 1]$  and  $\lambda_l = [0.1, 1]$ . The results are very similar to those reported here.



where  $\kappa$  is the steady-state value of capital requirement ratio.  $Y$  and  $L$  are steady-state values of output and total loans, respectively.  $\chi_l \geq 0$  measures the extent to which capital requirement ratio reacts to the credit-to-output gap. The CcCR rule is consistent with the main objective of macroprudential policy: to protect the banking sector from excessive fluctuations in the credit-to-output ratio which could have dire consequences for financial stability and negative spillover on the real economy.

Regime III is a combination of the CcCR rule (4.45) and an augmented Taylor rule as follows:

$$R_t = R \left( \frac{R_{t-1}}{R} \right)^{\phi_r} \left[ \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi} \left( \frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \left( \frac{L_t}{L_{t-1}} \right)^{\phi_l} \right]^{(1-\phi_r)}, \quad (4.46)$$

where  $\phi_l$  measures the extent to which the policy rate reacts to credit growth. The choice of credit growth rather than other financial variables such as house prices is motivated by the empirical findings in the literature that excessive fluctuations in a measure of credit (credit growth or credit-to-output ratio) is a robust indicator of a build-up of systemic risk (e.g., Schularick and Taylor, 2012; Gourinchas and Obstfeld, 2012; Mallick and Sousa, 2013; Jordà et al., 2015; Taylor, 2015). Furthermore, credit-driven bubbles are easier to measure, monitor, predict and control than asset price bubbles (Verona et al., 2017).

We then compute the optimal combination of the policy parameters  $(\phi_\pi^*, \phi_y^*, \phi_l^*, \chi_l^*)$  in Eqs. (4.39), (4.45) and (4.46) by minimising the welfare loss function Eq. (4.44), subject to the constraints given by the model.<sup>23</sup> We perform the grid search over the ranges  $\phi_\pi = [1.1, 3]$ ,  $\phi_y = [0, 1]$ ,  $\phi_l = [0, 0.2]$ ,  $\chi_l = [0, 10]$ , following the literature (see for e.g., Schmitt-Grohé and Uribe, 2007; Lambertini et al., 2013; Bailliu et al., 2015; Verona et al., 2017). We set the upper bound for  $\phi_l$  to be less than that for  $\phi_\pi$  because the primary objective of monetary policy is price stability. We assume that monetary policy provides a supporting role only to the financial stability objective. On the other hand, we set the upper bound for  $\chi_l$  higher because the primary objective of macroprudential policy is financial stability.

### 4.5.3 Optimal simple rules

In this section we present the results of the optimal policy analysis: the optimal combination of policy parameters, welfare gain or loss, and standard deviations of the variables in the loss function relative to those under the benchmark regime. The top panel of Table 4.5 shows the

<sup>23</sup>As in Bailliu et al. (2015), we fix the smoothing parameter ( $\rho_r$ ) at the estimated value to avoid a highly volatile policy rate and optimise over other policy parameters in the Taylor rule.

results of the optimal combination of a standard monetary policy rule and a macroprudential policy rule (regime II) while the bottom panel shows those of the optimal combination of an augmented monetary policy rule and the macroprudential policy rule (regime III). To provide a more intuitive analysis, we conduct the optimal policy analysis conditional on specific shocks: housing demand shock (column 2), LTV shocks (column 3) and NPL shocks (column 4). The choice of these shocks is motivated by the findings in the literature that macroprudential policies are effective in mitigating the impact of financial shocks, but inefficient for non-financial shocks (Kannan et al., 2012; Angelini et al., 2014; Benes and Kumhof, 2015). For robustness purposes we also conduct the analysis for a technology shock in columns 5 and for all the shocks considered in the paper in column 6. As mentioned previously, we set all other parameters at their posterior means from the estimation.

The results show that both the optimal standard monetary policy rule and the optimal augmented monetary policy rule feature a moderate reaction to inflation in the ranges of 1.1 to 1.5, which are lower than the estimated value of 1.70. This implies that a strong reaction to inflation is not optimal when the central bank pursues both financial and macroeconomic stability mandates using the two policy instruments. These results hold across the five shock scenarios. It is also evident that the optimal standard and augmented monetary policy rules feature a stronger response to output than the estimated response of 0.56 under the benchmark regime. The optimal coefficient on output remains virtually unchanged across the five shock scenarios, especially under regime II. Across all the shock scenarios, the optimal coefficient on credit growth hits the upper bound of 0.2. Regarding the optimal design of macroprudential policy, the results suggest that the central bank should adjust the capital requirement ratio proportionately to the credit-to-output gap (i.e.,  $\chi_l \approx 1$ ). These results hold in both regime II and regime III and regardless of the source of the shock.

Turning to the welfare effect, the results suggest that the optimal combination of the monetary policy (standard or augmented) rule and the macroprudential policy rule enhances the central bank's ability to minimise the welfare loss. In comparison to the benchmark regime, both regimes II and III yield welfare gains regardless of the source of shock. Such welfare gains are far larger under regime III than under regime II.

It is evident that under regime II the welfare gains are mainly coming from the reduced volatilities of output, credit-to-output ratio and house prices. The volatility of inflation, however, increases. This trade-off between financial stability and price stability worsens under

Table 4.5: Optimal policy parameters, welfare and standard deviations.

Parameter	Housing demand shock	LTV shocks	NPL shocks	Technology shock	All shocks
<b>Regime II (<math>\phi_r = 0.47</math>):</b>					
$\phi_\pi$	1.20	1.10	1.10	1.10	1.16
$\phi_y$	1.00	1.00	1.00	1.00	1.00
$\chi_l$	1.12	1.12	1.12	1.12	1.12
Welfare gain (%)	23.09	26.19	21.39	10.11	20.03
Standard deviation relative to benchmark					
$\pi_t$	2.20	1.40	1.67	2.59	1.45
$Y_t$	0.90	0.71	0.75	0.98	0.97
$L_t/Y_t$	0.86	0.86	0.89	0.27	0.84
$q_t$	0.99	0.76	0.75	0.99	0.99
<b>Regime III (<math>\phi_r = 0.47</math>):</b>					
$\phi_\pi$	1.25	1.31	1.53	1.10	1.25
$\phi_y$	1.00	1.00	1.00	0.93	1.00
$\phi_l$	0.20	0.20	0.20	0.20	0.20
$\chi_l$	1.12	1.12	1.12	1.12	1.12
Welfare gain (%)	33.52	40.27	30.33	10.32	28.14
Standard deviation relative to benchmark					
$\pi_t$	5.60	4.20	2.00	2.78	1.51
$Y_t$	0.83	0.54	0.75	0.97	0.97
$L_t/Y_t$	0.79	0.77	0.83	0.29	0.77
$q_t$	0.99	0.78	0.92	0.98	0.99

Notes: Welfare gain is calculated as the percentage difference between welfare loss under the benchmark regime and an alternative policy regime (II or III). That is,  $Welfare\ gain = 100 * [(\mathcal{L}_{benchmark} - \mathcal{L}_{alternative})/\mathcal{L}_{benchmark}]$ . A positive value implies a welfare gain under an alternative regime. The standard deviation relative to the benchmark is calculated by dividing the standard deviation of a given variable  $i$ ,  $i = \{\pi, y, l/y, q\}$ , under an alternative regime by the standard deviation under the benchmark regime. That is,  $\sigma_{i,alternative}^2/\sigma_{i,benchmark}^2$ . A value less than 1 means that an alternative regime reduces the volatility of variable  $i$  relative to the benchmark regime.

regime III where the central bank adjusts the policy rate to credit growth in addition to inflation and output growth. In this case, the increase in financial stability comes at the cost of a much larger increase in the volatility of inflation. These findings are consistent with Gelain et al. (2013) and Tayler and Zilberman (2016), in which the authors note that a policy regime that combines an augmented monetary policy and macroprudential policy generates a trade-off between price and financial stability. In separate experiments, we set the upper bound for  $\phi_l$  greater than 0.2. The results of these experiments are very similar to those reported here. The only difference is that financial stability benefits increase further at a much higher cost of increasing volatility of inflation than reported here. Furthermore, such experiments result in

large values of the optimal policy coefficients on credit growth, in which case the objective of financial stability dominates that of price stability in the setting of the policy rate. We try to avoid such unrealistic scenario in our analysis. Besides, Schmitt-Grohé and Uribe (2007) note that large values of the optimal policy coefficients are difficult to communicate to policymakers or the public.<sup>24</sup>

## 4.6 Impulse response analysis

To gain more insights into how monetary policy interacts with macroprudential policy, we present the impulse responses of the key variables following housing demand, LTV and NPL shocks. We contrast the benchmark regime with the two alternative policy regimes. We use the parameter values derived from the optimal rule analysis reported in Table 4.5 for the parameters in the monetary policy and macroprudential policy rules. We set other parameter values at their posterior means obtained from the estimation.

Fig. 4.2 shows the impulse responses of the key variables following a positive housing demand shock. Under the benchmark regime, the shock generates expansionary effects in the economy. It increases house prices and, through collateral constraints, leads to an increase in both household loans and entrepreneur loans. This in turn stimulates consumption and output growth. The policy rate increases and inflation decreases. Lending rates increase following the increase in demand for loans. When the central bank adopts regime II, we see the expansionary effect of the housing demand shock is dampened. The central bank increases the capital requirement ratio as the credit-to-output ratio increases. This prompts the bank to adjust its balance sheet by reducing the supply of credit (loans) relative to the supply under the benchmark regime. The reduction in credit supply induces borrowers to reduce their demand for housing. This dampens the increase in house prices and thus mitigates the amplification effect of the borrowing constraints. Consequently, consumption and output do not increase as much as under the benchmark regime.

Regime III significantly attenuates the expansionary effect of the shock, mainly through two channels. First, it works through the intertemporal substitution effect of the monetary policy on savers. The further increase in the policy rate prompts patient households to substitute from

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<sup>24</sup>Agénor et al. (2013) also note that allowing the policy rate to react aggressively to financial variables (credit growth or credit-to-output ratio) increases the volatility of the policy rate which could be a concern for the central bank as it could generate instability in the economy.

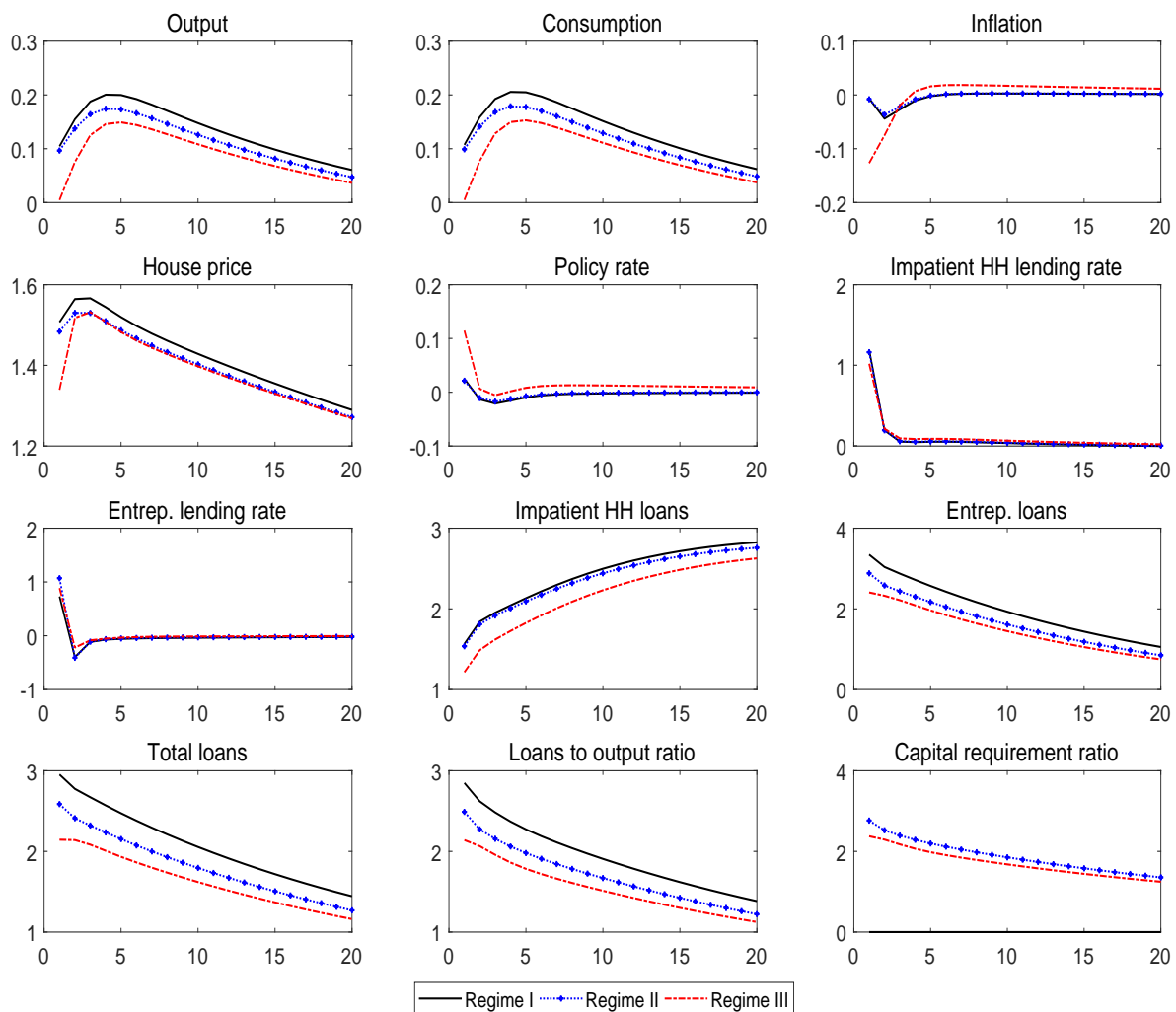


Figure 4.2: Impulse responses to a positive housing demand shock under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

consumption to savings. This causes the increase in aggregate consumption and output to decline under regime III. Second, it works through the expectation effect of the monetary policy. Intuitively, in a policy regime where monetary policy also responds to credit growth, private agents would expect the policy rate to react more aggressively than in a policy regime where monetary policy does not respond to financial conditions. Under regime III, forward-looking borrowers take into account the potential further increase in the policy rate when making economic decisions, and react by borrowing less. Hence, household loans and entrepreneur loans increase much less than under regime II. This in turn helps the central bank to implement a relatively easier macroprudential policy. In other words, the augmented Taylor rule helps to foster financial stability.

The attenuation effect of regime III, however, does not come for free. Consistent with the findings in the previous section, it is evident that the central bank faces a more severe trade-off between price and financial stability under regime III. A further increase in the policy rate stabilises credit market, house prices and output, but exacerbates the fluctuation of inflation. This suggests that regime III creates conflicts between price and financial stability objectives. The fall in inflation requires the central bank to reduce the policy rate, while the credit market boom requires the central bank to increase it. However, this policy conflict is absent under regime II because here monetary policy focuses solely on its primary objective of price stability, not financial stability.

We now turn to the impact of the credit market shocks (household LTV and NPL shocks). Fig. 4.3 shows the impulse response functions (IRFs) of the key variables following a positive household LTV shock.<sup>25</sup> Under the benchmark regime, the shock increases the borrowing capacity of impatient households and leads to an increase in the demand for housing and an increase in house prices. Both impatient households and entrepreneurs increase their demand for loans and thus stimulate aggregate spending and production. The increase in demand for loans prompts banks to increase the lending rates. The expansionary effect of the shock pushes up inflation. The policy rate increases initially to counteract the increase in inflation.

As in the case of the housing demand shock, a simultaneous deployment of monetary and macroprudential policies dampens the expansionary effects of the LTV shock. Under regime II, the central bank tightens the capital requirement regulation when the credit-to-output ratio increases. This induces the bank to adjust its balance sheet by reducing the supply of loans to impatient households and entrepreneurs. As a result, both impatient households and entrepreneurs reduce spending, including investment in housing. This in turn dampens the increase in house prices and thus mitigates the amplification effect of the borrowing constraint on the real sector. As a consequence, consumption and output increase by less under regime II than under the benchmark regime.

The results suggest that regime III is more effective than regime II in dampening fluctuations in total loans, house prices, consumption and output following a positive household LTV shock. As in the case of the housing demand shock, this attenuation effect comes at a higher cost in terms of the trade-off between price and financial stability. Specifically, regime III enhances

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<sup>25</sup>For brevity, we report only the impulse response functions to a positive household LTV shock. Similar results as those reported here also hold for the case of a positive entrepreneur LTV shock. The only notable difference is that impatient household lending rate declines under regime III in the case of a shock to entrepreneur LTV. The results are reported in appendix C.7.1.

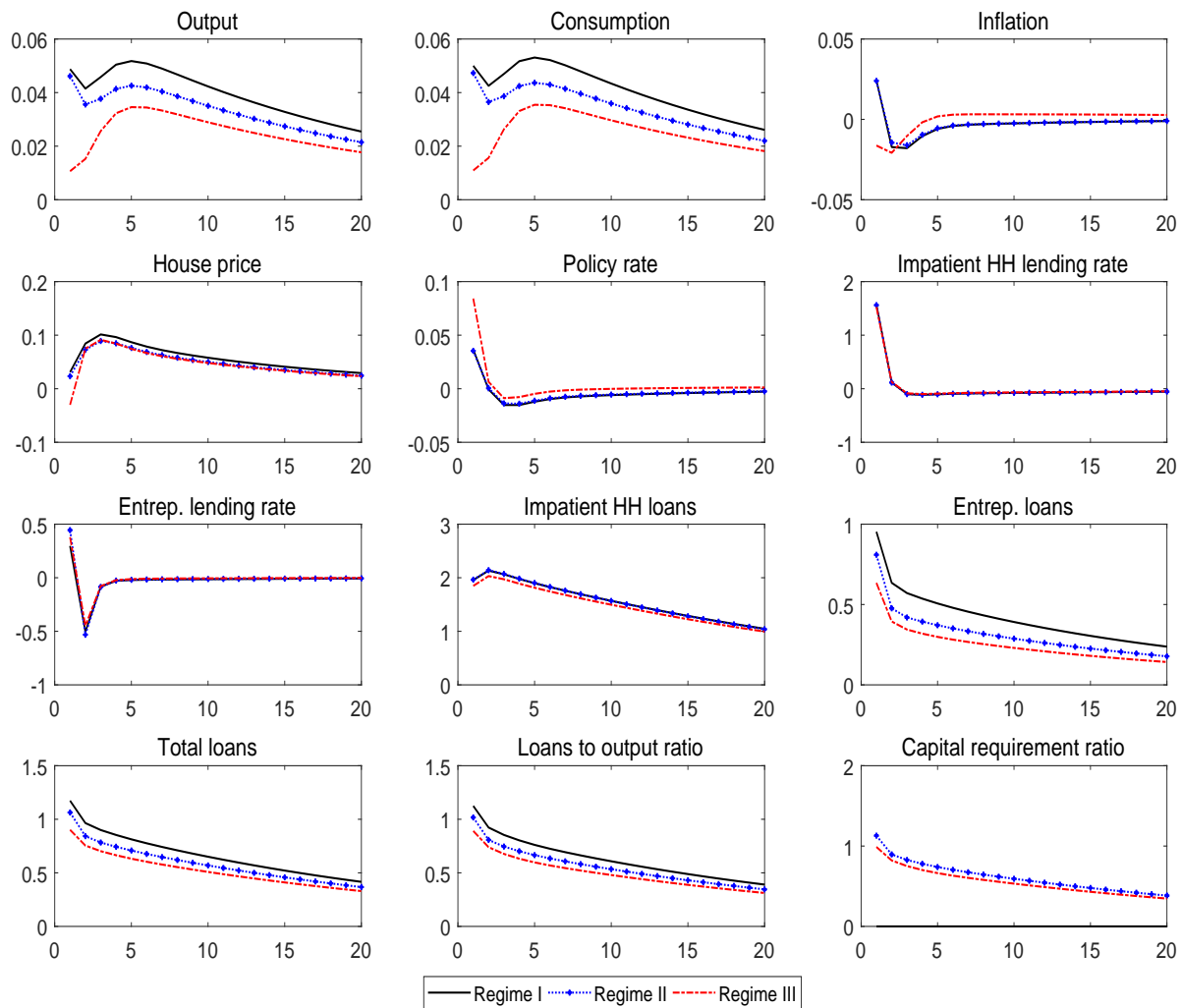


Figure 4.3: Impulse responses to a positive household LTV shock under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

financial stability at the cost of destabilising inflation.

In Fig. 4.4 we compare the responses of the key variables to a negative household NPL shock under the three policy regimes.<sup>26</sup> The shock affects financial variables mainly through the bank balance sheet channel. Under the benchmark regime, the shock increases the ratio of impatient households' NPLs and leads to an increase in the banks' loan losses. This in turn reduces the banks' net worth (bank capital) and forces them to reduce the total supply of loans in order to meet the capital requirement. Because the NPL shock occurs in the household loan sector of the credit market, the decrease in household loans is much larger than that in

<sup>26</sup>For brevity, we report only the impulse responses of the key variables to a negative household NPL shock. The results for a negative entrepreneur NPL shock are qualitatively similar to those reported here. The results are reported in appendix C.7.2.

entrepreneur loans.

In addition to this indirect effect stemmed from the balance sheet adjustment, the shock prompts the banks to increase lending rates in response to an increase in the perceived credit risk and in an attempt to rebuild their net worth by increasing interest rate earnings. This further weakens the demand for loans, and prompts borrowers to reduce spending, including investment in housing. House prices decrease as the demand for housing falls, and this generates a negative housing wealth effect, leading to a fall in consumption and output. The central bank increases the policy rate to counteract the increase in inflation.

Regime II dampens the negative impact of the shock. In this case, the central bank relaxes the capital requirement regulation as credit-to-output ratio declines. This reduces the pressure on banks to adjust their balance sheet as aggressively as under the benchmark regime. As a result, total loans fall by less under regime II than under the benchmark regime. This mitigates the spillover effects of the shock on the housing market and the real sector. As a consequence, house prices, consumption and output decline by less under regime II than under the benchmark regime.

Fig. 4.4 also shows that regime III enhances this stabilisation effect through the expectation channel of monetary policy and the intertemporal substitution effect of monetary policy. In this case, the policy rate increases less than under regime II. This is because the policy rate also responds to the decline in credit growth. Because of a smaller increase in the policy rate, inflation increases more under regime III than under regime II. As a result, the real interest rate decreases more and this in turn prompts patient households to increase consumption and reduce investment in housing due to the intertemporal substitution effect. In the anticipation of a smaller increase in the policy rate, both types of borrowers increase their borrowing. Consequently, impatient households' and entrepreneurs' spending, including investment in housing, fall by less under regime III than that under regime II. This mitigates the fall in house prices and, through the borrowing constraint, mitigates the negative impact of the shock on the real sector. Similar to the cases of housing demand shock and LTV shock, we find that regime III outperforms regime II in dampening fluctuations in the credit market, the housing market and the real sector. But this comes at the expense of increasing fluctuations in inflation.

The main conclusions we can draw from this analysis are as follows. A policy regime that combines a standard monetary policy rule and a macroprudential policy rule delivers a more stable economic system than a regime that combines an augmented monetary policy rule and



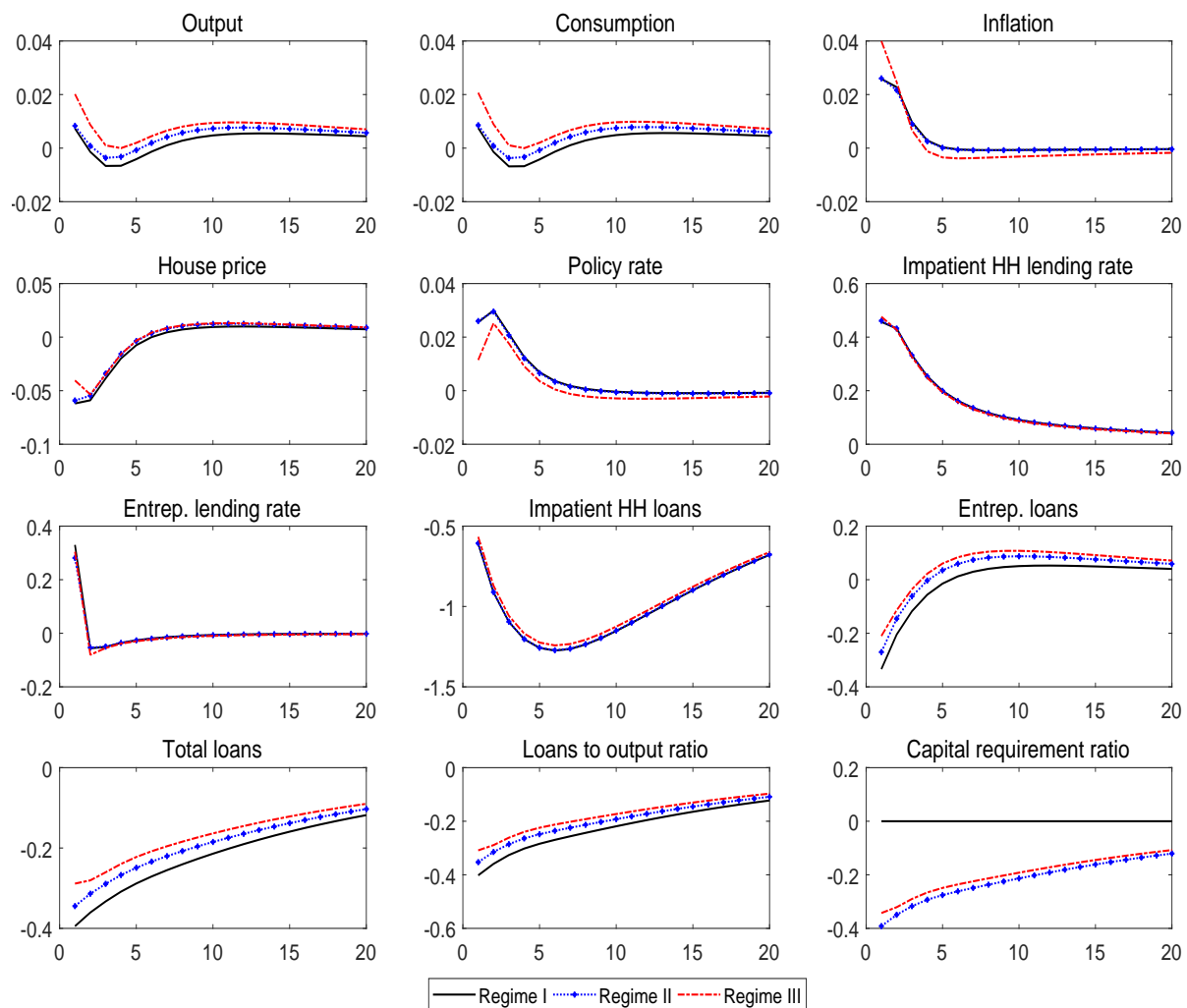


Figure 4.4: Impulse responses to a negative shock to impatient household non-performing loans under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

a macroprudential policy rule. The central bank faces a trade-off between price and financial stability objectives when monetary policy also responds to credit growth. While this policy regime seems to be effective from the financial stability point of view, it can compromise price stability, as noted by Tayler and Zilberman (2016). This is especially the case when shocks generate a negative correlation between credit and inflation. As noted in our analysis, a housing demand, LTV or NPL shock generates a negative correlation between credit and inflation. The central bank is forced to choose between price stability and financial stability when deploying an augmented monetary policy rule. The policy rate response required to achieve price stability is inconsistent with that required to achieve financial stability. For example, a positive housing demand shock increases credit but reduces inflation. While the fall in inflation calls for a

reduction in the policy rate, a boom in the credit market calls for an increase. The opposite is also true in the case of a negative shock. As we have seen in the impulse response analysis, this conflict compromises the central bank's ability to deliver on its price stability mandate. Nevertheless, the trade-off between price and financial stability is minimised and the policy conflict is absent under regime II.

## 4.7 Efficient policy frontiers

In this section we compare the three policy regimes in terms of two-dimensional efficient policy frontiers. The efficient policy frontier shows the locus of the volatilities of key policy variables (inflation and credit-to-output ratio), calculated for each set of optimal policy coefficients that are obtained for different combinations of loss function weights. To perform the exercise, we simplify the loss function (4.44) by setting the weights on the volatilities of output and house prices to 0.5 and 0.1 ( $\lambda_y = 0.5$  and  $\lambda_q = 0.1$ ), respectively, and allow the weight on the volatility of credit-to-output ratio to vary within the range  $\lambda_{l/y} \in [0, 1]$ . That is,

$$\mathcal{L} = \sigma_\pi^2 + 0.5\sigma_y^2 + \lambda_{l/y}\sigma_{l/y}^2 + 0.1\sigma_q^2. \quad (4.47)$$

Fig. 4.5 shows the efficient policy frontiers when the economy faces housing demand, LTV and NPL shocks considered in the previous section. Moving from right to left in Fig. 4.5, the weight on the volatility of credit-to-output ratio ( $\lambda_{l/y}$ ) increases from 0 to 1. A curve closer to the origin represents a more efficient (preferred) policy regime. We see that the introduction of macroprudential policy enhances both financial and price stability, especially regime II. That is, given the same weight on the volatility of credit-to-output ratio ( $\lambda_{l/y}$ ) in the loss function, regime II delivers a more efficient policy outcome in terms of a lower volatility of inflation and the credit-to-output ratio. A comparison between regime II and regime III suggests that regime III is more effective than regime II in promoting financial stability. However, this can only be achieved at a much higher cost of price stability.

The efficient policy frontiers under the three policy regimes present a clear trade-off between inflation and credit-to-output ratio volatilities, as the central bank adjusts its preference for stabilising the credit-to-output ratio relative to stabilising inflation. The maximum attainable reduction in credit-to-output volatility can be achieved at the expense of increasing inflation volatility, especially under regime III. Moreover, the relatively inelastic efficient policy frontiers, especially when the economy faces a housing demand shock, imply that it is not wise

for the central bank to put a relatively high weight on the credit-to-output ratio in its loss function. This is because a marginal reduction in the volatility of credit-to-output ratio is achieved at a relatively high cost in terms of the volatility of inflation.

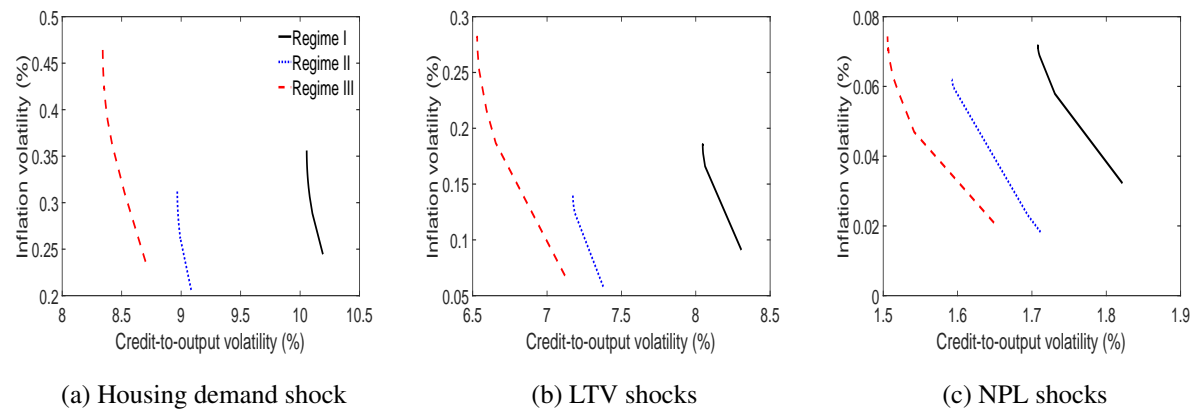


Figure 4.5: The efficient policy frontiers: inflation vs credit-to-output ratio ( $\lambda_{l/y} \in [0, 1]$ ).

Fig. 4.6 shows, with the presence of macroprudential policy, the trade-off between the volatilities of output and inflation when the economy faces housing demand, LTV and NPL shocks. The efficiency policy frontiers under the three policy regimes present a clear trade-off between inflation and output volatility, as the central bank adjusts its preference for stabilising the credit-to-output ratio relative to stabilising inflation and output. The results show that the introduction of macroprudential policy (regime II) shifts the efficiency frontier to the left, implying a more efficient policy outcome in terms of reducing the volatilities of inflation and output relative to the benchmark regime (regime I). This implies that macroprudential policy enhances the effectiveness of monetary policy. When the central bank implements a policy regime III, we see that the frontier shifts further to the left and up. This means that allowing monetary policy to react to financial imbalances weakens monetary policy's ability to deliver on its primary objective - price stability.

The efficient policy frontier analysis reaffirms the findings in the previous section. A policy regime that combines a standard monetary policy and macroprudential policy enhances both macroeconomic (price) stability and financial stability. This policy regime delivers the maximum attainable financial stability benefits at the lowest cost of price stability. These findings also concur with Rubio and Carrasco-Gallego (2014), in which the authors establish that a policy combination of a standard monetary policy and countercyclical LTV regulation enhances the overall economic stability. In addition, our analysis suggests that a policy regime that

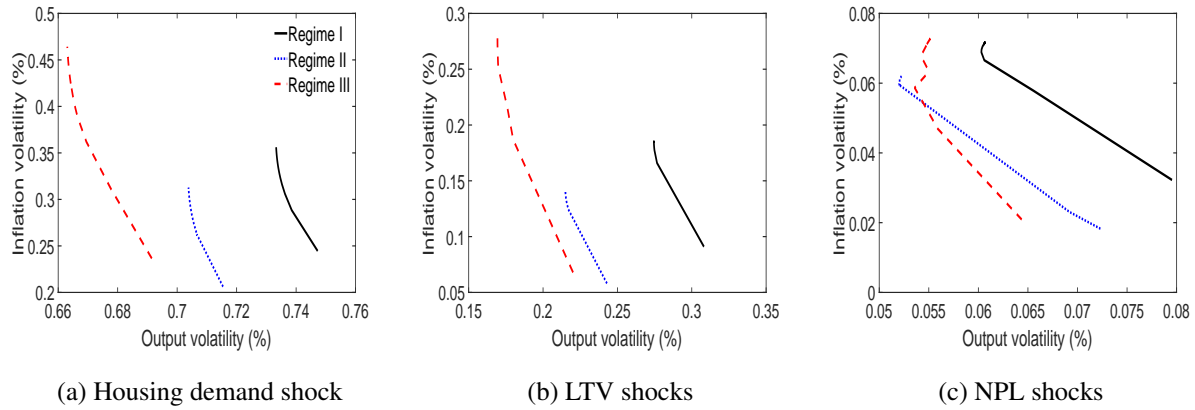


Figure 4.6: The efficient policy frontiers: inflation vs output ( $\lambda_{l/y} \in [0, 1]$ ).

combines an augmented monetary policy and macroprudential policy can compromise price stability, consistent with Rubio (2016) and Gelain et al. (2013).

## 4.8 Conclusion

This paper investigates the optimal design and the interaction between monetary and macroprudential policies for the South African economy. We find that a simultaneous deployment of monetary and macroprudential policies enhances macroeconomic (price) and financial stability. A policy regime that combines an augmented monetary policy with macroprudential policy delivers the highest welfare gains, but at a much higher cost of price instability than a regime that combines a standard monetary policy with macroprudential policy. An efficient policy frontier analysis shows that a combination of a standard monetary policy and a macroprudential policy is the most efficient policy regime in terms of enhancing both macroeconomic and financial stability.

The policy implication of our findings is that the central bank should be cautious when allowing monetary policy to react to financial conditions. In particular, our analysis suggests that the central bank should not use monetary policy to lean against the wind of credit cycles in an attempt to promote financial stability. Rather the central bank should introduce macroprudential policy instruments (like CcCR, studied here) with a primary objective of financial stability, and let monetary policy focus exclusively on its primary objective of price stability. Such a policy coordination will facilitate a simultaneous pursuit of both macroeconomic (price) and financial stability objectives as documented in Badarau and Popescu (2014) and Cesa-Bianchi and Rebucci (2017).

# Chapter 5

## Summary

In the aftermath of the 2007/08 financial crisis, consensus emerged among world leaders to adopt macroprudential policies with the overall objective of financial stability. This ignited a wave of research to enhance our understanding of how macroprudential policies work including their interaction with other policies such as monetary policy. This thesis contributes to this growing literature in three main respects.

The main contribution of Chapter 2 lies on its ability to provide some general guidance on appropriate design and implementation of Basel III countercyclical capital buffers. In Chapter 2 a real business cycle dynamic stochastic general equilibrium (DSGE) model that features a stylised banking sector, a housing market and a role of a macroprudential authority in implementing bank capital requirement regulation is developed. The calibrated model is then used, first, to investigate the extent to which Basel III countercyclical capital requirements attenuate fluctuations in credit and housing markets and mitigate the pro-cyclicality of Basel II bank capital regulations in the context of South Africa. This is done by decomposing the transition from Basel II to Basel III bank capital regulations into two stages - the permanent increase of the capital requirement ratio (CRR) by 2.5% in line with the capital conservation buffer and the additional countercyclical capital buffer. Second, a comparative assessment of four Basel III countercyclical capital requirement rules, in terms of enhancing financial and macroeconomic stability, is performed. The main findings in chapter 2 are as follows. The rule-based Basel III countercyclical capital requirements are effective in attenuating fluctuations in the credit and housing markets and in mitigating the pro-cyclicality of the Basel II capital regulation. The impact of a permanent increase in capital requirement ratio (a 2.5% conservation capital buffer) is marginal. The comparative assessment of four Basel III countercyclical capital requirement

rules suggests that the most effective rule for enhancing financial and macroeconomic stability is the one in which the authority adjusts CRR to deviations of credit and output from their steady states.

Chapter 3 extends the model in Chapter 2 to incorporate a role of a macroprudential authority in implementing countercyclical loan-to-value (CcLTV) regulation. The calibrated model is then used to investigate the implications of the CcLTV regulation in a setting where two types of borrowers (households and non-financial corporates) from distinct sectors of the credit market co-exist. This is done by comparing the effectiveness of two policy regimes for the implementation of the CcLTV regulations - one generic and one sector-specific - in terms of financial and macroeconomic stability. Under the generic regime, the authority adjusts household and corporate LTV ratios to changes in aggregate credit and output whilst adjusting these ratios according to specific sectoral credit conditions and output, with different intensities, under the sector-specific regime. The findings in chapter 3 suggest that both the generic and the sector-specific regimes are effective in enhancing financial and macroeconomic stability. The comparative assessment of the two policy regimes depends on the source of economic disturbances in the economy. The two policy regimes are equally effective and therefore can serve as substitutes when the economy faces a technology shock. However, when one sector of the credit market is hit by a financial shock, the sector-specific regime outperforms the generic regime. The generic regime outperforms the sector-specific regime when the economy is hit by a housing demand shock that has similar spillover effects on household and corporate credit markets. The main policy implication of these findings is that the regulator should assess potential risks in the specific sectors of credit market and tailor the CcLTV regulation according to the specific financial conditions of each sector rather than tailoring the regulation according to aggregate financial conditions. Specifically, the findings highlight the risks associated with the implementation of a "one-size-fits-all" CcLTV regulation, and emphasis on the importance of identifying the source of economic disturbances for the appropriate implementation of the CcLTV regulation.

In Chapter 4 a new Keynesian DSGE model which features a stylised banking sector, a housing market and the role of monetary and macroprudential policies is developed and estimated using Bayesian techniques. The estimated model is then used to compare the effectiveness of a simultaneous deployment of monetary and macroprudential policies under the two alternative policy regimes against a benchmark regime in which there is only monetary pol-

icy. The first alternative regime is a combination of a standard monetary policy and a macroprudential policy for countercyclical capital requirements. The second alternative regime is a combination of an augmented monetary policy and countercyclical capital requirements. The findings in Chapter 4 suggest that the policy regime that combines a standard monetary policy and macroprudential policy enhances both macroeconomic stability and financial stability. The regime that combines an augmented monetary policy and macroprudential policy is superior in enhancing output and financial stability, but compromises price stability. The findings in this chapter provide an alternative explanation on why monetary policy should not account for financial stability objective as this threatens central bank's ability to foster price stability. In particular, the findings suggest that monetary policy should focus solely on its primary objective of price stability and let macroprudential policy facilitates financial stability on its own. Such a policy coordination facilitates a simultaneous pursuit of both macroeconomic (price) and financial stability objectives.

To further enhance our understanding of macroprudential policies, the analysis in this thesis can be developed further in several directions. One possible avenue is to extend the analysis to a small open economy model and study the role of macroprudential policies in mitigating the impact of foreign financial shocks. Such an extension can also provide richer information about dynamics in the economy and form part of an analytical contribution towards the development of a modelling framework that incorporates the role of financial sector.

# **Appendices**



# Appendix A

## Housing and credit market shocks: Exploring the role of rule-based Basel III countercyclical capital requirements

### A.1 Complete set of equations for the baseline model<sup>1</sup>

#### Households

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_t N_t + R_{d,t-1} D_{t-1}, \quad (\text{A.1.1})$$

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \quad (\text{A.1.2})$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \quad (\text{A.1.3})$$

$$W_t = \frac{\tau}{(1 - N_t) U_{Cs,t}}, \quad (\text{A.1.4})$$

where  $U_{Cs,t} = (1 - \eta_s)/(C_{s,t} - \eta_s C_{s,t-1})$ .

#### Entrepreneurs

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t} L_{e,t-1} + W_t N_t + A C_{le,t} = Y_t + L_{e,t} + \zeta_t, \quad (\text{A.1.5})$$

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<sup>1</sup>The implied steady-states of the model as well as the codes used for producing the results are available upon request.

$$Y_t = Z_t H_{e,t-1}^\nu N_t^{1-\nu}, \quad (\text{A.1.6})$$

$$L_{e,t} = m_e E_t \left( \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right), \quad (\text{A.1.7})$$

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \nu \frac{Y_{t+1}}{H_{e,t}} + (1 - m_e) q_{t+1} \right) + m_e E_t \frac{q_{t+1}}{R_{e,t+1}} - m_e AC'_{le,t} E_t \frac{q_{t+1}}{R_{e,t+1}}, \quad (\text{A.1.8})$$

$$(1 - \nu) Y_t = W_t N_t, \quad (\text{A.1.9})$$

where  $U_{Ce,t} = (1 - \eta_e)/(C_{e,t} - \eta_e C_{e,t-1})$ ,  $AC_{le,t} = (\phi_{le}/2L_e)(L_{e,t} - L_{e,t-1})^2$  and  $AC'_{le,t} = (\phi_{le}/L_e)(L_{e,t} - L_{e,t-1})$ .

## Banks

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{e,t} + AC_{lf,t} = D_t + R_{e,t} L_{e,t-1} - \zeta_t, \quad (\text{A.1.10})$$

$$D_t = (1 - \kappa_t)[L_{e,t} - \zeta_{t+1}], \quad (\text{A.1.11})$$

$$1 - (1 - \kappa_t) + AC'_{ef,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} (R_{e,t+1} - (1 - \kappa_t) R_{d,t}), \quad (\text{A.1.12})$$

where  $AC_{ef,t} = (\phi_{ef}/2L_e)(L_{e,t} - L_{e,t-1})^2$ ,  $AC'_{ef,t} = (\phi_{ef}/L_e)(L_{e,t} - L_{e,t-1})$  and  $U_{Cf,t} = (1 - \eta_f)/(C_{f,t} - \eta_f C_{f,t-1})$ .

## Aggregate consumption and market clearing conditions

$$C_t = C_{s,t} + C_{e,t} + C_{f,t}. \quad (\text{A.1.13})$$

$$H_{s,t} + H_{e,t} = 1. \quad (\text{A.1.14})$$

## Interest rate spread

$$Sprd_t = R_{e,t} - R_{d,t}. \quad (\text{A.1.15})$$

## Macroprudential policy rule

$$\kappa_t = \kappa \left( \frac{L_{e,t}/Y_t}{L_e/Y} \right)^{\chi_x}. \quad (\text{A.1.16})$$

## Shock processes

$$\log(A_t) = \rho_a \log(A_{t-1}) + \xi_{a,t}, \quad (\text{A.1.17})$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \xi_{\zeta,t}, \quad (\text{A.1.18})$$

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}. \quad (\text{A.1.19})$$

## A.2 Complete set of equations for the extended model

### Patient households (savers)

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_{s,t}N_{s,t} + R_{d,t-1}D_{t-1}, \quad (\text{A.2.1})$$

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \quad (\text{A.2.2})$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \quad (\text{A.2.3})$$

$$W_{s,t} = \frac{\tau}{(1 - N_{s,t}) U_{Cs,t}}, \quad (\text{A.2.4})$$

where  $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t}-\eta_s C_{s,t-1}}$ .

### Impatient households (borrowers)

$$C_{b,t} + R_{b,t-1}L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) + AC_{lb,t} = W_{b,t}N_{b,t} + L_{b,t} + \zeta_{b,t}, \quad (\text{A.2.5})$$

$$L_{b,t} \leq m_b E_t \left[ \frac{q_{t+1}}{R_{b,t}} H_{b,t} \right], \quad (\text{A.2.6})$$

$$1 = \beta_b E_t \frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t} + \frac{\lambda_{b,t}}{U_{Cb,t}} + \frac{\phi_{lb}}{L_b} (L_{b,t} - L_{b,t-1}), \quad (\text{A.2.7})$$

$$q_t = j \frac{A_t}{H_{b,t} U_{Cb,t}} + \beta_b E_t \left( \frac{U_{Cb,t+1}}{U_{Cb,t}} \right) q_{t+1} + m_b (\lambda_{b,t} / U_{Cb,t}) E_t \frac{q_{t+1}}{R_{b,t}}, \quad (\text{A.2.8})$$

$$W_{b,t} = \frac{\tau}{(1 - N_{b,t}) U_{Cb,t}}, \quad (\text{A.2.9})$$

where  $U_{Cb,t} = \frac{1-\eta_b}{C_{b,t}-\eta_b C_{b,t-1}}$  and  $AC_{lb,t} = (\phi_{lb}/2L_b)(L_{b,t} - L_{b,t-1})^2$ .

## Entrepreneurs

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_{s,t}N_{s,t} + W_{b,t}N_{b,t} + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \quad (\text{A.2.10})$$

$$L_{e,t} \leq m_e E_t \left[ \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right], \quad (\text{A.2.11})$$

$$Y_t = Z_t H_{e,t-1}^\nu [N_{s,t}^{1-\sigma} N_{b,t}^\sigma]^{1-\nu}. \quad (\text{A.2.12})$$

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \nu \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) + m_e (\lambda_{e,t} / U_{Ce,t}) E_t \frac{q_{t+1}}{R_{e,t+1}}, \quad (\text{A.2.13})$$

$$W_{s,t}N_{s,t} = (1 - \sigma)(1 - \nu)Y_t, \quad (\text{A.2.14})$$

$$W_{b,t}N_{b,t} = \sigma(1 - \nu)Y_t, \quad (\text{A.2.15})$$

$$1 - \frac{\phi_{le}}{L_e}(L_{e,t} - L_{e,t-1}) = \lambda_{e,t} / U_{Ce,t} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}. \quad (\text{A.2.16})$$

where  $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$  and  $AC_{le,t} = (\phi_{le}/2L_e)(L_{e,t} - L_{e,t-1})^2$ .

## Banks

$$C_{f,t} + R_{d,t-1}D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1}L_{b,t-1} + R_{e,t}L_{e,t-1} - \zeta_{b,t} - \zeta_{e,t}, \quad (\text{A.2.17})$$

$$D_t \leq (1 - w_e \kappa_t)[L_{e,t} - E_t \zeta_{e,t+1}] + (1 - w_b \kappa_t)[L_{b,t} - E_t \zeta_{b,t+1}], \quad (\text{A.2.18})$$

$$1 - \lambda_{f,t} / U_{Cf,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t}, \quad (\text{A.2.19})$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (\lambda_{f,t}/U_{Cf,t})(1 - w_e \kappa_t) + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}), \quad (\text{A.2.20})$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t} = 1 - (\lambda_{f,t}/U_{Cf,t})(1 - w_b \kappa_t) + \frac{\phi_{bf}}{L_b} (L_{b,t} - L_{b,t-1}), \quad (\text{A.2.21})$$

where  $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t}-\eta_f C_{f,t-1}}$ ,  $AC_{ef,t} = (\phi_{ef}/2L_e)(L_{e,t}-L_{e,t-1})^2$  and  $AC_{ef,t} = (\phi_{ef}/2L_e)(L_{e,t}-L_{e,t-1})^2$ .

### Aggregate Consumption and market clearing conditions

$$C_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t}, \quad (\text{A.2.22})$$

$$H_{s,t} + H_{b,t} + H_{e,t} = 1, \quad (\text{A.2.23})$$

$$L_{b,t} + L_{e,t} = L_t. \quad (\text{A.2.24})$$

### Interest rate spreads

$$Sprd_{b,t} = R_{b,t} - R_{d,t}, \quad (\text{A.2.25})$$

$$Sprd_{e,t} = R_{e,t} - R_{d,t}. \quad (\text{A.2.26})$$

### Macprudential policy rule

$$\kappa_t = \kappa \left( \frac{L_t/Y_t}{L/Y} \right)^{\chi_x}. \quad (\text{A.2.27})$$

### Shock processes

$$\log(A_t) = \rho_a \log(A_{t-1}) + \xi_{a,t}, \quad (\text{A.2.28})$$

$$\zeta_{b,t} = \rho_\zeta \zeta_{b,t-1} + \xi_{\zeta_b,t}, \quad (\text{A.2.29})$$

$$\zeta_{e,t} = \rho_\zeta \zeta_{e,t-1} + \xi_{\zeta_e,t}, \quad (\text{A.2.30})$$

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}. \quad (\text{A.2.31})$$

### A.3 Data and sources

The data are obtained from the South African Reserve Bank database. The exceptions is house price data from ABSA bank

1. **Output** ( $y_t$ ): real GDP, quarterly, seasonally adjusted at annual rate.
2. **Consumption** ( $c_t$ ): Final consumption expenditure by households, quarterly, seasonally adjusted at annual rate.
3. **Household loans** ( $L_{b,t}$ ): Total credit to households (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards and other loans and advances), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
4. **Entrepreneur (Corporate) loans** ( $L_{e,t}$ ): Total credit to non-financial corporates (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards, other loans and advances and investments and bills), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
5. **Household deposits** ( $D_t$ ): Banking institutions: Residents: Households deposits.
6. **Bank capital** ( $BK_t$ ): Liabilities of banking institutions: Share capital and reserves.
7. **Household lending rate** ( $R_{b,t}$ ): Predominant rate: Mortgages.
8. **Corporate lending rate** ( $R_{e,t}$ ): Predominant prime lending rate.
9. **House prices** ( $q_t$ ): Middle-segment nominal house price index (seasonally adjusted) obtained from ABSA bank. This index is available monthly, and is converted to quarterly values based on a three-month average. The use of the entire middle-segment house price data set is justified on the basis that these data are regarded as the most representative of the general house price level prevailing in the South African economy (Aye et al., 2014, 476). These data are deflated by the GDP deflator to get the real counterpart.
10. **Inflation** ( $\pi_t$ ): Inflation is measured by quarterly changes in implicit GDP deflator.

## A.4 Results with the extended model: Rule-based Basel III countercyclical capital requirements

In the following we present the simulation results with the extended model under the two Basel regimes to get more insight on the impact of the Rule-based Basel III countercyclical capital requirements. We first consider a positive housing demand shock and then a negative financial shock. For the sake of brevity, we discuss the results for the variables that have been affected by the modifications in the extended model in more detail and only briefly summarise the rest. The discussion focuses on a complete transition to the Basel III regulation.<sup>2</sup>

### A.3.1 Housing demand shock

Figure A.1 depicts the impulse responses of the main variables to a positive housing demand shock. The shock increases house prices and, through the borrowing constraint channel, results in an increase in impatient households' and entrepreneurs' demand for credit. This stimulates output growth and consumption for impatient households, entrepreneurs and banks. For patient households, the increased preference for housing services creates incentives for them to substitute from consumption goods to housing services. As such, patient households' consumption declines.

Under Basel III (red solid line), capital requirement ratio increases in response to the increase in the credit-to-output ratio. To meet higher capital requirement ratio, banks refrain from providing more credit to entrepreneurs and impatient households. This attenuates the extent of the increase in entrepreneurs' and impatient households' demand for housing, house prices and output. This is in contrast to the case under the Basel II regime. Under Basel II (black asterisk lines), the decrease of capital requirement promotes more lending and amplifies the impact of the shock on fluctuations in both financial and real variables. These results concur with the findings in the literature (see e.g., Repullo and Suarez, 2013; Angeloni and Faia, 2013; Angelini et al., 2014, 2015; Gersbach and Rochet, 2017), where the authors show that Basel III is effective in mitigating pro-cyclical effects of Basel II and has potential to promote financial stability.

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<sup>2</sup>We exclude the Basel II.5 regime in this section.

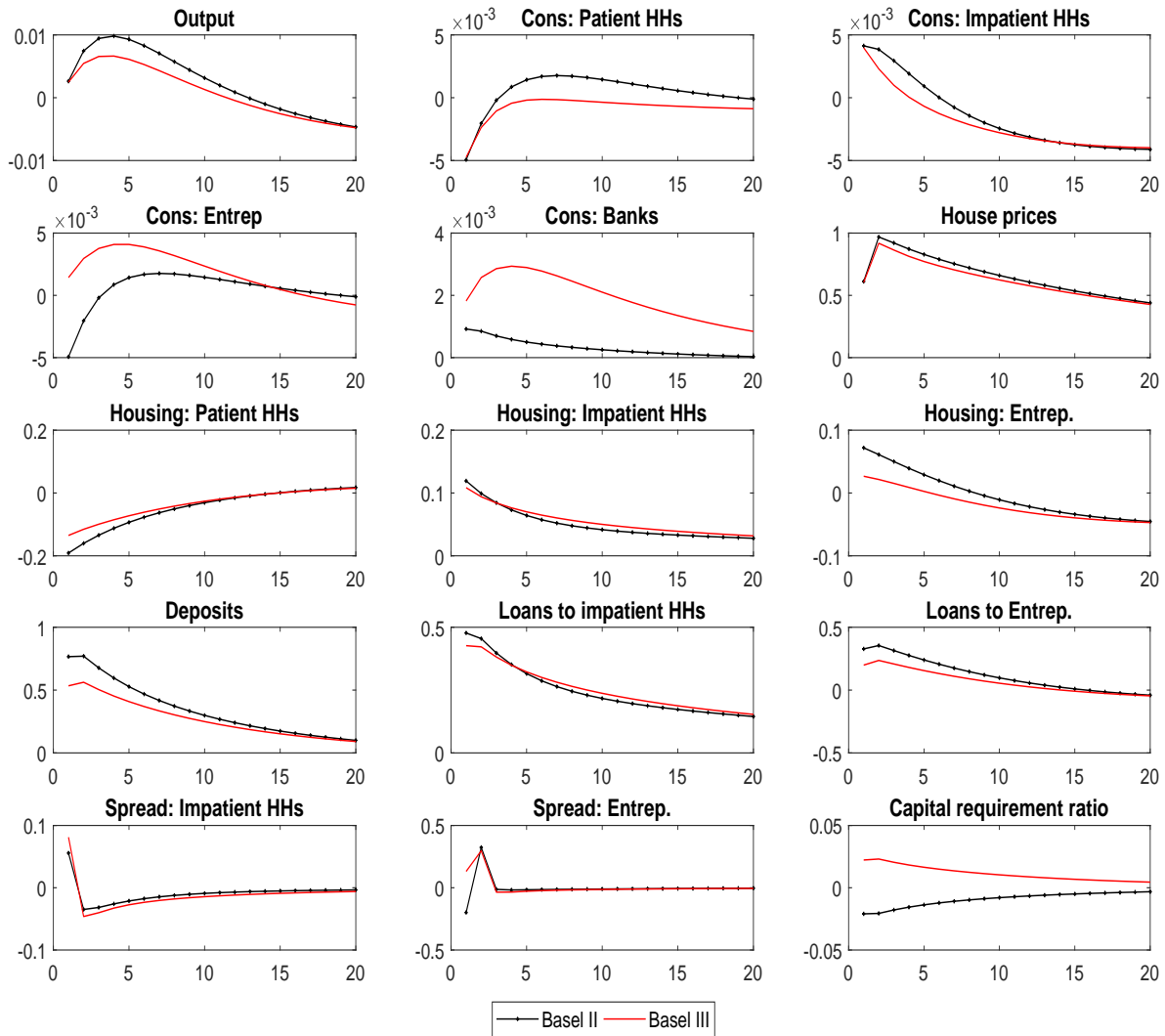


Figure A.1: Impulse responses to a positive housing demand shock under two Basel regimes. Notes: Black asterisk lines: Basel II; Red solid line: Basel III. Variables are expressed in % deviations from steady states, interest rates are in percentage points. Cons, HHs and Entrep stand for consumption, households and entrepreneur.

### A.3.2 Loan repayment shock (impatient household)

Figure A.2 shows the impulse responses of the main variables following a negative loan repayment shock, corresponding to an unexpected increase in loan losses on impatient households loans.<sup>3</sup> The shock reduces banks' net worth and, through the bank capital constraint channel, leads to a fall in credit supply to both impatient households and entrepreneurs. As a consequence, borrowers' (impatient households and entrepreneurs) demand for housing and house

<sup>3</sup>In this section, we only report the results for the impatient household loan repayment shock. The results for the entrepreneur loan repayment shock are similar to those of the impatient household loan repayment shock. The only difference is that, in the case of the entrepreneur loan repayment shock, entrepreneurs' consumption increases while that of impatient households does not. Furthermore, additional resources (due to income redistribution from banks to entrepreneurs) enable entrepreneurs to hire more labour and boost production over time.



prices declines. The shock also results in a protracted decline in output and agents' consumption except for impatient households. For impatient households, the shock increases their income: by paying less than the contractual amount of loans, borrowers are able to spend more than previously anticipated.

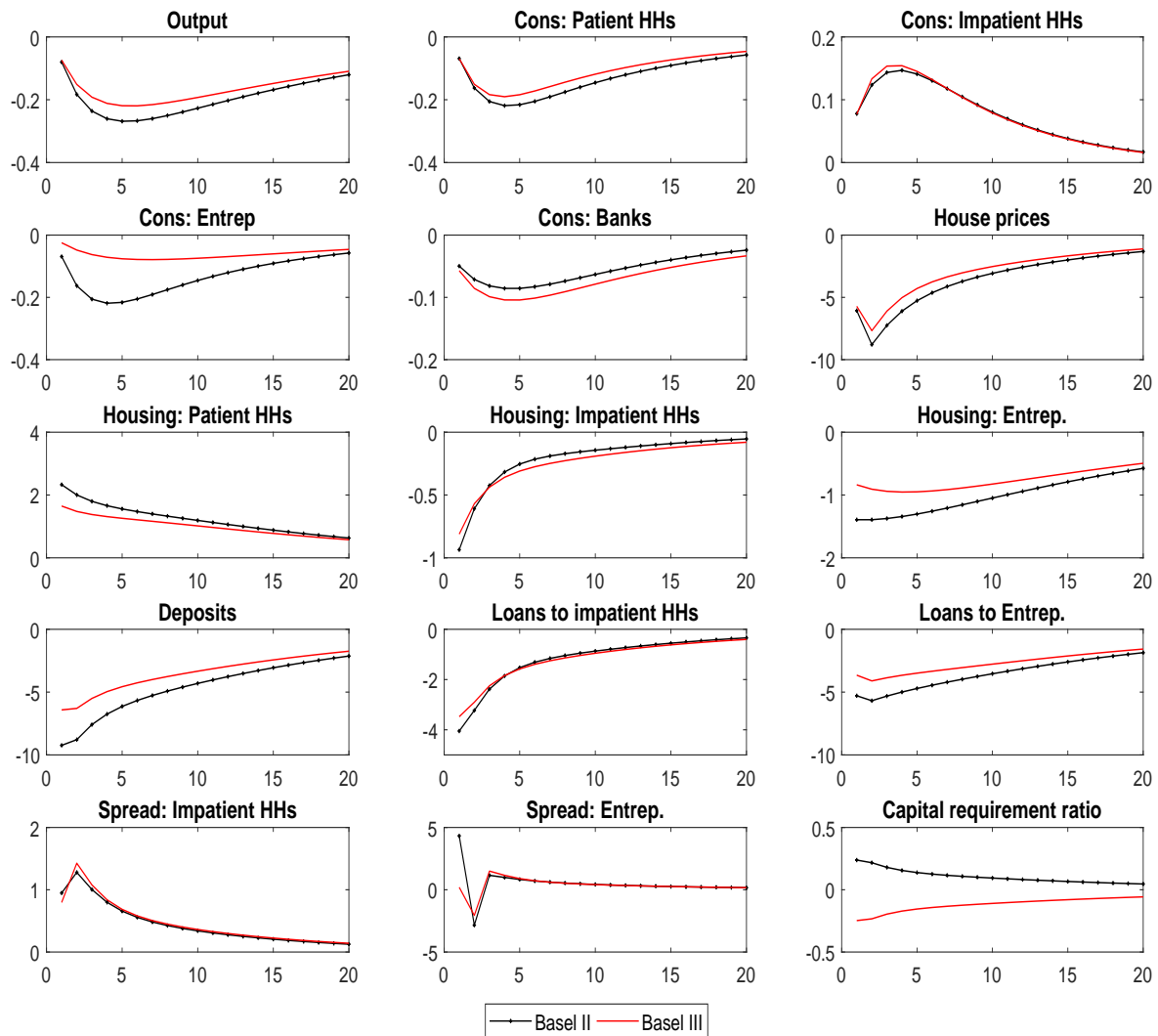


Figure A.2: Impulse responses to a negative loan repayment shock (impatient household) under two Basel regimes. Notes: Black asterisk lines: Basel II; Red solid lines: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points. Cons, HHs and Entrep stand for consumption, households and entrepreneur.

Under the Basel II regime (black asterisk lines), capital requirement ratio increases as credit-to-output fall. This forces banks to adjust their balance sheet by curtailing demand for deposits and credit supply. Lending rates also increase, especially on impact. These exacerbate the recessionary effects of the shock and induces a large fall in impatient households' and entrepreneurs' demand for housing, consumption and output. In contrast, under the Basel III

regime (red solid line), the regulatory requirement becomes accommodative and bank capital requirement ratio temporarily falls. This assists banks to better absorb the impact of the shock without being forced to reduce credit rapidly. Consequently, the extent of the fall in credit supply becomes smaller under Basel III than under Basel II. This also mitigates the fall in impatient household' and entrepreneurs' demand for housing and output. Banks further curtail consumption and make additional resources available for lending.

## Appendix B

# The effectiveness of the countercyclical loan-to-value regulation: generic versus sector-specific rules

### B.1 Complete set of equations for the model<sup>1</sup>

#### Patient households (Savers)

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_{s,t}N_{s,t} + R_{d,t-1}D_{t-1}, \quad (\text{B.1})$$

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \quad (\text{B.2})$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left( \frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \quad (\text{B.3})$$

$$W_{s,t} = \frac{\tau}{(1 - N_{s,t}) U_{Cs,t}}, \quad (\text{B.4})$$

where  $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t}-\eta_s C_{s,t-1}}$ .

#### Impatient households (Borrowers)

$$C_{b,t} + R_{b,t-1}L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) = W_{b,t}N_{b,t} + L_{b,t} + \zeta_{b,t}, \quad (\text{B.5})$$

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<sup>1</sup>The implied steady-states of the model as well as the codes used for producing the results are available upon request.

$$L_{b,t} = m_{b,t} E_t \left[ \frac{q_{t+1}}{R_{b,t}} H_{b,t} \right], \quad (\text{B.6})$$

$$1 = \beta_b E_t \frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t} + \frac{\lambda_{b,t}}{U_{Cb,t}}, \quad (\text{B.7})$$

$$q_t = j \frac{A_t}{H_{b,t} U_{Cb,t}} + \beta_b (1 - m_{b,t}) E_t \left( \frac{U_{Cb,t+1}}{U_{Cb,t}} \right) q_{t+1} + m_{b,t} E_t \frac{q_{t+1}}{R_{b,t}}, \quad (\text{B.8})$$

$$W_{b,t} = \frac{\tau}{(1 - N_{b,t}) U_{Cb,t}}, \quad (\text{B.9})$$

where  $U_{Cb,t} = (1 - \eta_b) / (C_{b,t} - \eta_b C_{b,t-1})$ .

## Entrepreneurs

$$C_{e,t} + q_t (H_{e,t} - H_{e,t-1}) + R_{e,t} L_{e,t-1} + W_{s,t} N_{s,t} + W_{b,t} N_{b,t} = Y_t + L_{e,t} + \zeta_{e,t}, \quad (\text{B.10})$$

$$Y_t = Z_t H_{e,t-1}^\nu [N_{s,t}^{1-\sigma} N_{b,t}^\sigma]^{1-\nu}, \quad (\text{B.11})$$

$$L_{e,t} = m_{e,t} E_t \left( \frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right), \quad (\text{B.12})$$

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left( \nu \frac{Y_{t+1}}{H_{e,t}} + (1 - m_{e,t}) q_{t+1} \right) + m_{e,t} E_t \frac{q_{t+1}}{R_{e,t+1}}, \quad (\text{B.13})$$

$$W_{s,t} N_{s,t} = (1 - \sigma)(1 - \nu) Y_t, \quad (\text{B.14})$$

$$W_{b,t} N_{b,t} = \sigma(1 - \nu) Y_t, \quad (\text{B.15})$$

where  $U_{Ce,t} = (1 - \eta_e) / (C_{e,t} - \eta_e C_{e,t-1})$ .

## The bank

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{b,t} + L_{e,t} + A C_{bf,t} + A C_{ef,t} = D_t + R_{b,t-1} L_{b,t-1} + R_{e,t} L_{e,t-1} - \zeta_t, \quad (\text{B.16})$$

$$D_t = (1 - w_e \kappa) (L_{e,t} - E_t \zeta_{e,t+1}) + (1 - w_b \kappa) (L_{b,t} - E_t \zeta_{b,t+1}), \quad (\text{B.17})$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t} = (1 - \lambda_{f,t}/U_{Cf,t}), \quad (\text{B.18})$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t} = 1 - (1 - w_b \kappa)(\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{bf}}{L_b}(L_{b,t} - L_{b,t-1}). \quad (\text{B.19})$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (1 - w_e \kappa)(\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}), \quad (\text{B.20})$$

where  $U_{Cf,t} = (1 - \eta_f)/(C_{f,t} - \eta_f C_{f,t-1})$ ,  $AC_{bf,t} = \frac{\phi_{bf}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_b}$ ,  $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$ .

## Aggregate consumption and market clearing conditions

$$C_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t}. \quad (\text{B.21})$$

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \quad (\text{B.22})$$

$$L_{b,t} + L_{e,t} = L_t. \quad (\text{B.23})$$

## Household LTV rule

$$m_{b,t} = m_b \left( \frac{L_{b,t}}{L_b} \right)^{-\chi_l} \left( \frac{Y_t}{Y} \right)^{-\chi_y}, \quad (\text{B.24})$$

## Entrepreneur (corporate) LTV rule

$$m_{e,t} = m_e \left( \frac{L_{e,t}}{L_e} \right)^{-\chi_l} \left( \frac{Y_t}{Y} \right)^{-\chi_y}, \quad (\text{B.25})$$

## Shock processes

$$\log(A_t) = \rho_a \log(A_{t-1}) + \xi_{a,t}, \quad (\text{B.26})$$

$$\zeta_{b,t} = \rho_\zeta \zeta_{b,t-1} + \xi_{\zeta_{b,t}}, \quad (\text{B.27})$$

$$\zeta_{e,t} = \rho_\zeta \zeta_{e,t-1} + \xi_{\zeta_{e,t}}, \quad (\text{B.28})$$

$$\log(Z_t) = \rho_z \log(Z_{t-1}) + \xi_{z,t}. \quad (\text{B.29})$$

## B.2 Data and sources

The data are obtained from the South African Reserve Bank database. The exceptions is house price data from ABSA bank

1. **Output** ( $y_t$ ): real GDP, quarterly, seasonally adjusted at annual rate.
2. **Consumption** ( $c_t$ ): Final consumption expenditure by households, quarterly, seasonally adjusted at annual rate.
3. **Household loans** ( $L_{b,t}$ ): Total credit to households (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards and other loans and advances), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
4. **Entrepreneur (Corporate) loans** ( $L_{e,t}$ ): Total credit to non-financial corporates (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards, other loans and advances and investments and bills), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
5. **Household deposits** ( $D_t$ ): Banking institutions: Residents: Households deposits.
6. **Household lending rate** ( $R_{b,t}$ ): Predominant rate: Mortgages.
7. **Corporate lending rate** ( $R_{e,t}$ ): Predominant prime lending rate.
8. **House prices** ( $q_t$ ): Middle-segment nominal house price index (seasonally adjusted) obtained from ABSA bank. This index is available monthly, and is converted to quarterly values based on a three-month average. The use of the entire middle-segment house price data set is justified on the basis that these data are regarded as the most representative of the general house price level prevailing in the South African economy (Aye et al., 2014, 476). These data are deflated by the GDP deflator to get the real counterpart.
9. **Inflation** ( $\pi_t$ ): Inflation is measured by quarterly changes in implicit GDP deflator.

### B.3 Efficient policy frontier

In this section, we present the outcome of credit-output volatility trade-off for technology and housing demand shocks. The left panel in Fig. B.1 shows the results with productivity shock while the right panel shows the results with housing demand shock. The black square mark shows the outcome of credit-output volatility under the baseline regime (constant LTV ratios). This is compared with the outcome under the generic CcLTV regime (red dash-dot line) and the sector-specific regime (blue dashed line).

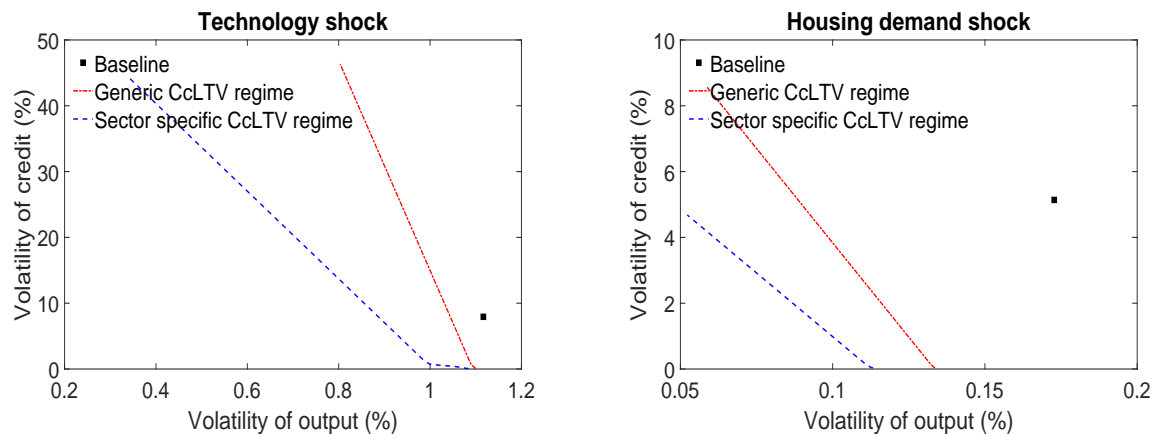


Figure B.1: Credit-output stability trade-off. Left panel: productivity shock; right panel: housing demand shock.

Consistent with the findings in the previous sections, the results show that the sector-specific regime is more effective than the generic regime in enhancing financial and macroeconomic stability. The volatility frontiers for the two shocks present a clear trade-off between financial and macroeconomic stability. It is evident that both regimes are more effective in enhancing financial stability but has limited impact in enhancing macroeconomic stability. The maximum attainable financial stability benefits can be achieved without compromising macroeconomic stability, irrespective of the shock hitting the economy. On the contrary, the maximum attainable macroeconomic stability benefits can only be achieved by compromising financial stability. With the exception of the sector-specific regime when the economy is hit by housing demand shock, a maximum attainable reduction in output volatility is only feasibly at a cost of higher credit volatility.

# Appendix C

## The optimal monetary and macroprudential policies for the South African economy

### C.1 Complete set of equations for the log-linearised model<sup>1</sup>

Variables with a hat denote percent deviations from steady state and those without a time subscript are steady states.

#### Patient Households

$$\hat{u}_{cs,t} = -\frac{1}{1 - \eta_s} (\hat{c}_{s,t} - \eta_s \hat{c}_{s,t-1}), \quad (\text{C.1})$$

$$E_t(\hat{u}_{cs,t+1} - \hat{u}_{cs,t}) + E_t(\hat{r}_t - \hat{\pi}_{t+1}) = 0, \quad (\text{C.2})$$

$$\hat{q}_t = (1 - \beta_s)(\hat{a}_{j,t} - \hat{h}_{s,t}) + \beta_s E_t \hat{u}_{cs,t+1} - \hat{u}_{cs,t} + \beta_s E_t \hat{q}_{t+1}, \quad (\text{C.3})$$

$$\hat{w}_{s,t} = \frac{n_s}{1 - n_s} \hat{n}_{s,t} - \hat{u}_{cs,t}, \quad (\text{C.4})$$

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<sup>1</sup>The implied steady-states of the model, full diagnostic statistics of the estimated model as well as the codes used for producing the results are available upon request.



$$\frac{c_s}{y}\hat{c}_{s,t} = \frac{wn_s}{y}(\hat{w}_{s,t} + \hat{n}_{s,t}) - \frac{qh_s}{y}(\hat{h}_{s,t} - \hat{h}_{s,t-1}) + \frac{x-1}{x}\hat{y}_t + \frac{1}{x}\hat{x}_t - \frac{d}{y}\left[\hat{d}_t - \frac{r}{\pi}(\hat{r}_{t-1} - \hat{\pi}_t + \hat{d}_{t-1})\right]. \quad (\text{C.5})$$

## Impatient Households

$$\hat{u}_{cb,t} = -\frac{1}{1-\eta_b}(\hat{c}_{b,t} - \eta_b\hat{c}_{b,t-1}), \quad (\text{C.6})$$

$$\hat{l}_{b,t} = E_t(\hat{q}_{t+1} + \hat{h}_{b,t} - \hat{r}_{b,t} + \hat{\pi}_{t+1}) + \hat{\gamma}_{b,t}, \quad (\text{C.7})$$

$$\Gamma_{b1}E_t(\hat{u}_{cb,t+1} - \hat{u}_{cb,t} + \hat{r}_{b,t} - \hat{\pi}_{t+1}) = \beta_b\zeta_b(1-\vartheta_b)\frac{r_b}{\pi}\hat{\zeta}_{b,t+1} - (1-\Gamma_{b1})(\hat{\lambda}_{b,t} - \hat{u}_{cb,t}), \quad (\text{C.8})$$

$$\hat{q}_t = (1-\Gamma_{b2})[\hat{a}_{j,t} - \hat{h}_{b,t} - \hat{u}_{cb,t}] + \Gamma_{b2}\hat{q}_{t+1} + (\Gamma_{b2} - \beta_b)[\hat{\lambda}_{b,t} - \hat{u}_{cb,t} + \hat{\gamma}_{b,t} - \hat{r}_{b,t} + \hat{\pi}_{t+1}] + \beta_b(\hat{u}_{cb,t+1} - \hat{u}_{cb,t}), \quad (\text{C.9})$$

$$\hat{w}_{b,t} = \frac{n_b}{1-n_b}\hat{n}_{b,t} - \hat{u}_{cb,t}, \quad (\text{C.10})$$

$$\hat{\zeta}_{b,t} = -\chi_{\zeta b}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\varepsilon}_{b,t}, \quad (\text{C.11})$$

$$\frac{c_b}{y}\hat{c}_{b,t} = \frac{wn_b}{y}(\hat{w}_{b,t} + \hat{n}_{b,t}) - \frac{qh_b}{y}(\hat{h}_{b,t} - \hat{h}_{b,t-1}) + \frac{l_b}{y}\left[\hat{l}_{b,t} - \frac{\Gamma_{b1}}{\beta_b}(\hat{l}_{b,t-1} + \hat{r}_{b,t-1} - \hat{\pi}_t) + \zeta_b(1-\vartheta_b)\frac{r_b}{\pi}\hat{\zeta}_{b,t}\right], \quad (\text{C.12})$$

where,  $\Gamma_{b1} = \beta_b\left[1 - \zeta_b(1 - \vartheta_b)\right]\frac{r_b}{\pi}$  and  $\Gamma_{b2} = \beta_b + m_b\left[\frac{\pi}{r_b} - \beta_b(1 - \zeta_b(1 - \vartheta_b))\right]$ .

## Entrepreneurs

$$\hat{u}_{ce,t} = -\frac{1}{1-\eta_e}(\hat{c}_{e,t} - \eta_e\hat{c}_{e,t-1}), \quad (\text{C.13})$$

$$\hat{l}_{e,t} = E_t(\hat{q}_{t+1} - \hat{r}_{e,t+1} + \hat{\pi}_{t+1} + \hat{h}_{e,t}) + \hat{\gamma}_{e,t}, \quad (\text{C.14})$$

$$\Gamma_{e1}E_t(\hat{u}_{ce,t+1} - \hat{u}_{ce,t} + \hat{r}_{e,t+1} - \hat{\pi}_{t+1}) = \beta_e \zeta_e (1 - \vartheta_e) \frac{r_e}{\pi} \hat{\zeta}_{e,t+1} - (1 - \Gamma_{e1})(\hat{\lambda}_{e,t} - \hat{u}_{ce,t}), \quad (\text{C.15})$$

$$\begin{aligned} \hat{q}_t = & (1 - \Gamma_{e2})(\hat{y}_{t+1} - \hat{x}_{t+1} - \hat{h}_{e,t}) + \Gamma_{e2}\hat{q}_{t+1} + (\Gamma_{e2} - \beta_e)(\hat{\lambda}_{e,t} - \hat{u}_{ce,t} - \hat{r}_{e,t+1} + \hat{\pi}_{t+1} + \hat{\gamma}_{e,t}) + \\ & (1 + \beta_e - \Gamma_{e2})(\hat{u}_{ce,t+1} - \hat{u}_{ce,t}), \end{aligned} \quad (\text{C.16})$$

$$\hat{w}_{s,t} = \hat{y}_t - \hat{x}_t - \hat{n}_{s,t}, \quad (\text{C.17})$$

$$\hat{w}_{b,t} = \hat{y}_t - \hat{x}_t - \hat{n}_{b,t}, \quad (\text{C.18})$$

$$\hat{y}_t = \hat{z}_t + \nu \hat{h}_{e,t-1} + (1 - \nu)(1 - \sigma)\hat{n}_{s,t} + \sigma(1 - \nu)\hat{n}_{b,t}, \quad (\text{C.19})$$

$$\hat{\zeta}_{e,t} = -\chi_{\zeta_e}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\varepsilon}_{e,t}, \quad (\text{C.20})$$

$$\begin{aligned} \frac{c_e}{y}\hat{c}_{e,t} = & \frac{l_e}{y} \left[ \hat{l}_{e,t} - \frac{r_e}{\pi} [1 - \zeta_e(1 - \vartheta_e)](\hat{l}_{e,t-1} + \hat{r}_{e,t} - \hat{\pi}_t) + \zeta_e(1 - \vartheta_e) \frac{r_e}{\pi} \hat{\zeta}_{e,t} \right] - \frac{qh_e}{y}(\hat{h}_{e,t} - \hat{h}_{e,t-1}) \\ & + \frac{1}{x}(\hat{y}_t - \hat{x}_t) - \frac{wn_s}{y}(\hat{w}_{s,t} + \hat{n}_{s,t}) - \frac{wn_b}{y}(\hat{w}_{b,t} + \hat{n}_{b,t}) \end{aligned} \quad (\text{C.21})$$

$$\text{where, } \Gamma_{e1} = \beta_e \left[ 1 - \zeta_e(1 - \vartheta_e) \right] \frac{r_e}{\pi} \text{ and } \Gamma_{e2} = \beta_e + m_e \left[ \frac{\pi}{r_e} - \beta_e \left( 1 - \zeta_e(1 - \vartheta_e) \right) \right].$$

## The bank

$$\hat{u}_{cf,t} = -\frac{1}{1 - \eta_f}(\hat{c}_{f,t} - \eta_f \hat{c}_{f,t-1}), \quad (\text{C.22})$$

$$\beta_f \frac{r}{\pi} E_t(\hat{r}_t - \hat{\pi}_{t+1}) = -\beta_f \frac{r}{\pi} E_t(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) - \lambda_{fss}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}), \quad (\text{C.23})$$

$$\begin{aligned} \Gamma_{fb2}(\hat{r}_{b,t} - \hat{\pi}_{t+1}) = & \left( \beta_f \frac{r_b}{\pi} - \Gamma_{fb2} \right) \hat{\zeta}_{b,t+1} - (1 - w_b \kappa) \lambda_{fss} \Gamma_{fb3}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_b \kappa \lambda_{fss} \Gamma_{fb3} \hat{\kappa}_t \\ & - \Gamma_{fb1}(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{bf}(\hat{l}_{b,t} - \hat{l}_{b,t-1}), \end{aligned} \quad (\text{C.24})$$

$$\begin{aligned}\Gamma_{fe2}(\hat{r}_{e,t+1} - \hat{\pi}_{t+1}) &= \left(\beta_f \frac{r_e}{\pi} - \Gamma_{fe2}\right) \hat{\zeta}_{e,t+1} - (1 - w_e \kappa) \lambda_{fss} \Gamma_{fe3} (\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_e \kappa \lambda_{fss} \Gamma_{fe3} \hat{\kappa}_t \\ &\quad - \Gamma_{fe1} (\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{ef} (\hat{l}_{e,t} - \hat{l}_{e,t-1}),\end{aligned}\tag{C.25}$$

$$\begin{aligned}\frac{d}{y} \hat{d}_t &= (1 - w_b \kappa) \frac{l_b}{y} \left[ \Gamma_{fb3} \hat{l}_{b,t} - \frac{r_b}{\pi} \zeta_b (\hat{r}_{b,t} - \hat{\pi}_{t+1} + \hat{\zeta}_{b,t+1}) \right] - w_b \kappa \Gamma_{fb3} \frac{l_b}{y} \hat{\kappa}_t - w_e \kappa \Gamma_{fe3} \frac{l_e}{y} \hat{\kappa}_t \\ &\quad + (1 - w_e \kappa) \frac{l_e}{y} \left[ \Gamma_{fe3} \hat{l}_{e,t} - \frac{r_e}{\pi} \zeta_e (\hat{r}_{e,t+1} - \hat{\pi}_{t+1} + \hat{\zeta}_{e,t+1}) \right],\end{aligned}\tag{C.26}$$

where,  $\Gamma_{fb1} = \beta_f \frac{r_b}{\pi} (1 - \zeta_b)$ ,  $\Gamma_{fb2} = \Gamma_{fb1} - (1 - w_b \kappa) \lambda_{fss} \frac{r_b}{\pi} \zeta_b$ ,  $\Gamma_{fb3} = 1 - \frac{r_b}{\pi} \zeta_b$ ,  $\Gamma_{fe1} = \beta_f \frac{r_e}{\pi} (1 - \zeta_e)$ ,  $\Gamma_{fe2} = \Gamma_{fe1} - (1 - w_e \kappa) \lambda_{fss} \frac{r_e}{\pi} \zeta_e$  and  $\Gamma_{fe3} = 1 - \frac{r_e}{\pi} \zeta_e$ .

### Aggregate consumption and market clearing conditions

$$\frac{c}{y} \hat{c}_t = \frac{c_s}{y} \hat{c}_{s,t} + \frac{c_b}{y} \hat{c}_{b,t} + \frac{c_e}{y} \hat{c}_{e,t} + \frac{c_f}{y} \hat{c}_{f,t},\tag{C.27}$$

$$\frac{h_s}{y} \hat{h}_{s,t} + \frac{h_b}{y} \hat{h}_{b,t} + \frac{h_e}{y} \hat{h}_{e,t} = 0,\tag{C.28}$$

$$\frac{l}{y} \hat{l}_t = \frac{l_b}{y} \hat{l}_{b,t} + \frac{l_e}{y} \hat{l}_{e,t}.\tag{C.29}$$

### Monetary policy rule, inflation dynamics and shock processes

$$\hat{r}_t = \phi_r \hat{r}_{t-1} + (1 - \phi_r) [\phi_\pi \hat{\pi}_t + \phi_y \Delta \hat{y}_t] + \xi_{r,t},\tag{C.30}$$

$$\hat{\pi}_t = \frac{\iota_p}{1 + \iota_p \beta_s} \hat{\pi}_{t-1} + \frac{\beta_s}{1 + \iota_p \beta_s} E_t \hat{\pi}_{t+1} - \frac{(1 - \theta)(1 - \beta_s \theta)}{(1 + \iota_p \beta_s) \theta} \hat{x}_t + \xi_{\pi,t},\tag{C.31}$$

$$\hat{a}_{j,t} = \rho_j \hat{a}_{j,t-1} + \xi_{j,t},\tag{C.32}$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \xi_{z,t},\tag{C.33}$$

$$\hat{\gamma}_{b,t} = \rho_{\gamma b} \hat{\gamma}_{b,t-1} + \xi_{\gamma b,t},\tag{C.34}$$

$$\hat{\gamma}_{e,t} = \rho_{\gamma e} \hat{\gamma}_{e,t-1} + \xi_{\gamma e,t}, \quad (\text{C.35})$$

$$\hat{\varepsilon}_{b,t} = \rho_{\varepsilon b} \hat{\varepsilon}_{b,t-1} + \xi_{\varepsilon b,t}, \quad (\text{C.36})$$

$$\hat{\varepsilon}_{e,t} = \rho_{\varepsilon e} \hat{\varepsilon}_{e,t-1} + \xi_{\varepsilon e,t}, \quad (\text{C.37})$$

where  $\xi_{i,t} \sim i.i.d.N(0, \sigma_i^2)$  is the white noise process, normally distributed with mean zero and variance  $\sigma_i^2$ ,  $\forall i = \{r, \pi, j, z, \gamma b, \gamma e, \varepsilon b, \varepsilon e\}$ .

## Measurement equation

The measurement equation describes how the empirical data (actual times series) is matched to the corresponding model variables:

$$\begin{bmatrix} \Delta \log(Y_t^{obs}) - \bar{\gamma}_y \\ \Delta \log(q_t^{obs}) - \bar{\gamma}_q \\ \Delta \log(L_{b,t}^{obs}) - \bar{\gamma}_{lb} \\ \Delta \log(L_{e,t}^{obs}) - \bar{\gamma}_{le} \\ \log(\Pi_t^{obs}) - \bar{\gamma}_\pi \\ \log(R_t^{obs}) - \bar{\gamma}_r \\ \log(\zeta_{b,t}^{obs}) - \bar{\gamma}_{\zeta_b} \\ \log(\zeta_{e,t}^{obs}) - \bar{\gamma}_{\zeta_e} \end{bmatrix} = \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{q}_t - \hat{q}_{t-1} \\ \hat{l}_{b,t} - \hat{l}_{b,t-1} \\ \hat{l}_{e,t} - \hat{l}_{e,t-1} \\ \hat{\pi}_t \\ \hat{r}_t \\ \hat{\zeta}_{b,t} \\ \hat{\zeta}_{e,t} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \xi_{\varepsilon b,t}^{me} \\ \xi_{\varepsilon e,t}^{me} \end{bmatrix}, \quad (\text{C.38})$$

where  $\Delta$  is the temporal difference operator and  $\bar{\gamma}_i$  is the sample mean of the respective transformed variables.  $\xi_{\varepsilon b,t}^{me}$  and  $\xi_{\varepsilon e,t}^{me}$  are measurement errors to allow for the fact that the data on household and entrepreneur NPLs is an approximation of the actual underlying series.

## C.2 Data and sources

Most of the data are obtained from the South African Reserve Bank database. The exceptions are house price data from ABSA bank, interest rate data from the IMF's International Financial Statistics database, and population data from the World Bank database.

1. **Output ( $y_t$ ):** real GDP, quarterly, seasonally adjusted at annual rate.

2. **Household loans** ( $L_{b,t}$ ): Total credit to households (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards and other loans and advances), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
3. **Entrepreneur (Corporate) loans** ( $L_{e,t}$ ): Total credit to non-financial corporates (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards, other loans and advances and investments and bills), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.
4. **House prices** ( $q_t$ ): Middle-segment nominal house price index (seasonally adjusted) obtained from ABSA bank. This index is available monthly, and is converted to quarterly values based on a three-month average. The use of the entire middle-segment house price data set is justified on the basis that these data are regarded as the most representative of the general house price level prevailing in the South African economy (Aye et al., 2014, 476). These data are deflated by the GDP deflator to get the real counterpart.
5. **Inflation** ( $\pi_t$ ): Inflation is measured by quarterly changes in the GDP deflator.
6. **Short-term nominal interest rate** ( $R_t$ ): 90-day treasury bill rate as a proxy for policy rate. Since nominal interest rate data are provided in an annualised form, we transformed these data into quarterly data by dividing the original data by 400 to match the frequency of the model. These data are obtained from the IMF's International Financial Statistics database.
7. **Population**: The population aged between 15 and 64. Data on population are obtained from World Bank database and available at annual frequency. To construct quarterly population data, we assume that the population increases at a linear rate throughout the year.
8. **Ratios of household and corporate NPLs (non-performing loans)** ( $\zeta_{b,t}$  and  $\zeta_{e,t}$ ): Impaired advances (advances in respect of which the bank has raised a specific impairment). These data are available only at aggregate level (total NPLs). To construct data on household NPLs, we multiply the ratio of household loans to total loans by total NPLs. We then divide the resulting household NPLs by household loans to get data on the ratio of

household NPLs  $(\zeta_{b,t})$ . We do the same to construct data on the ratio of corporate NPLs  $(\zeta_{e,t})$ .

## C.3 Prior and posterior density plots

### C.3.1 Structural parameters

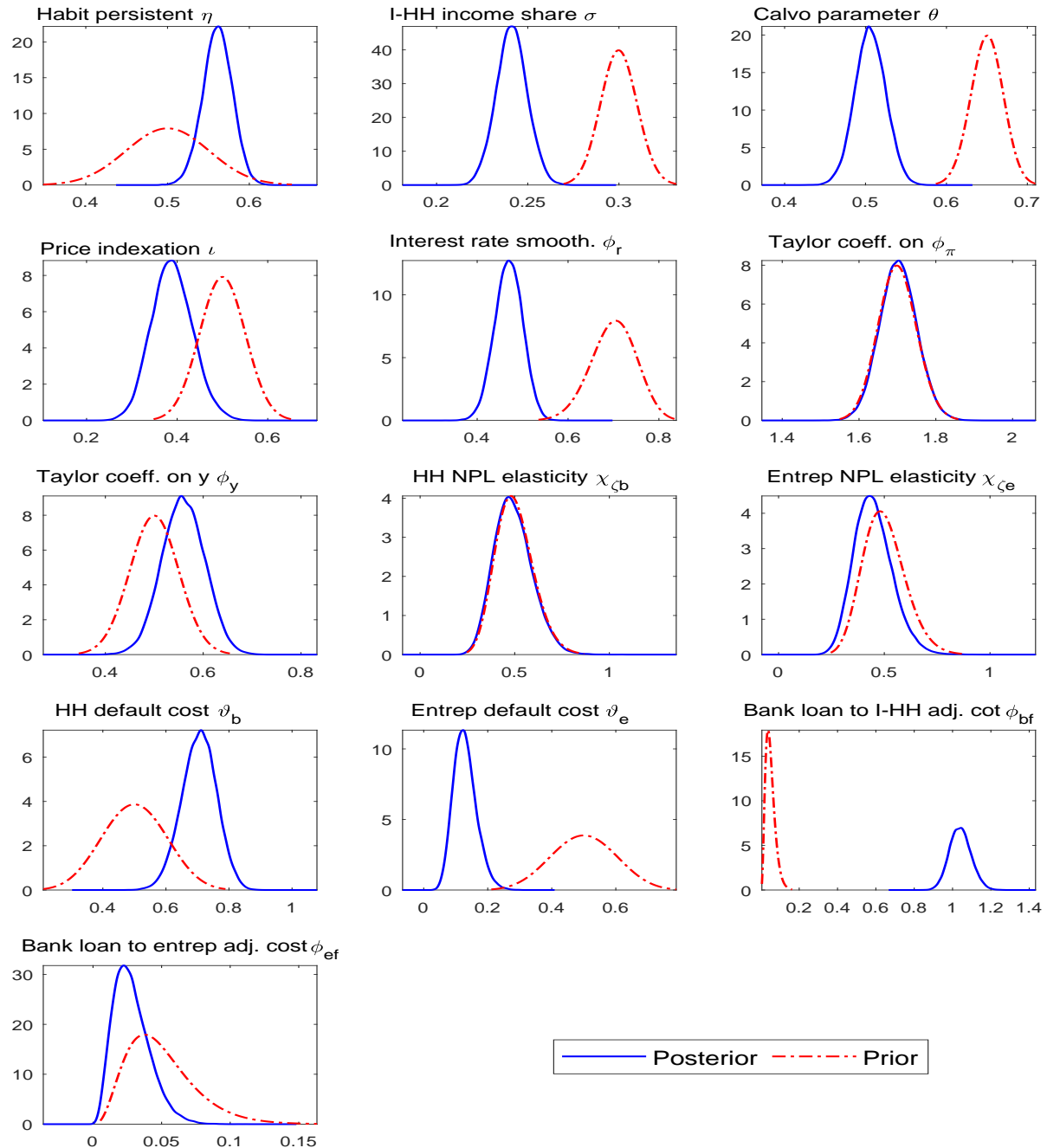


Figure C.3.1: Note: Blue solid lines denote the posterior distribution and red dashed lines the prior distribution. The marginal posterior densities are based on simulation using the Random-Walk Metropolis algorithm with 250,000 draws for two chains.

### C.3.2 Shock processes

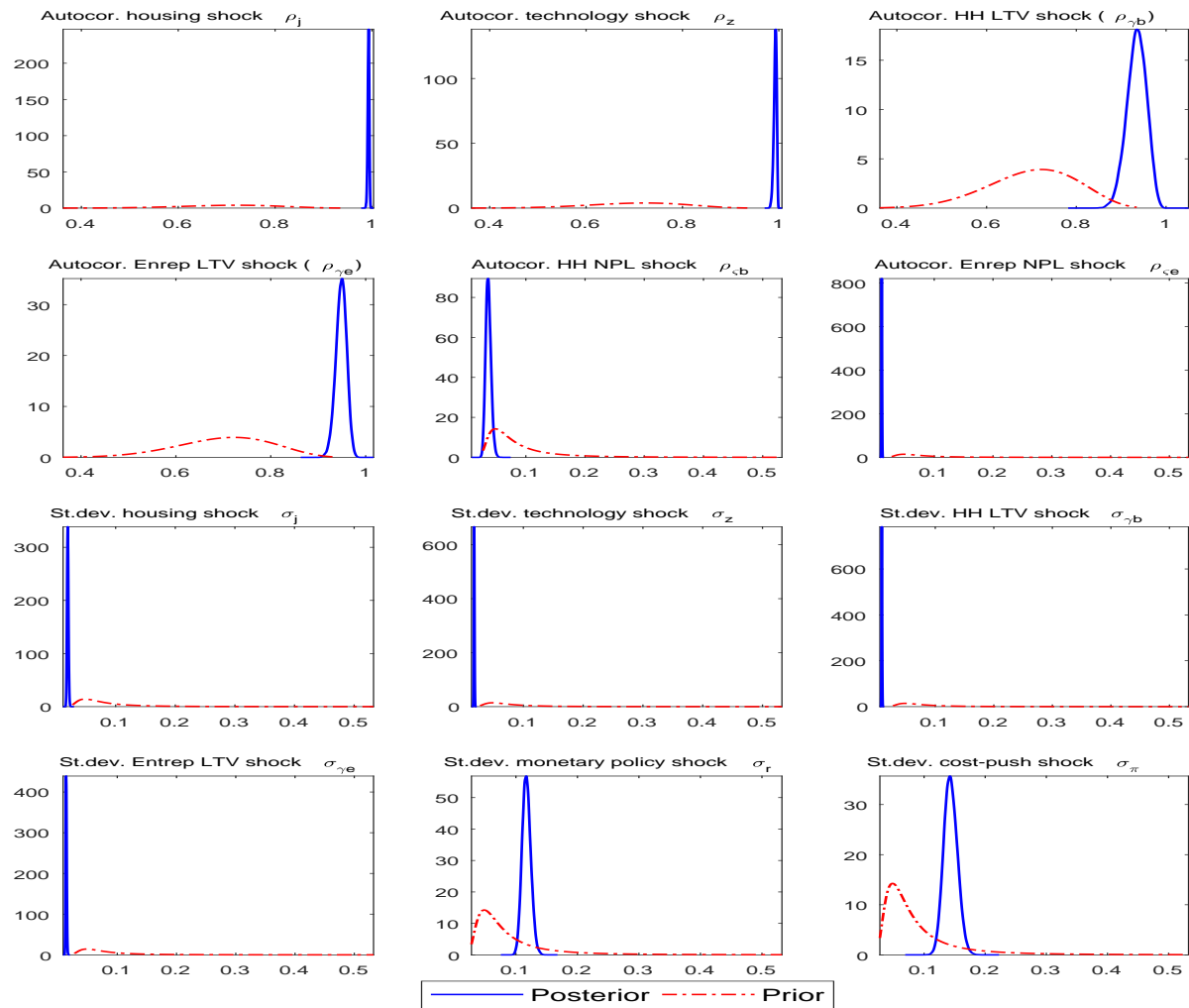


Figure C.3.2: Note: Blue solid lines denote the posterior distribution and red dashed lines the prior distribution. The marginal posterior densities are based on simulation using the Random-Walk Metropolis algorithm with 250,000 draws for two chains.

## C.4 Monte Carlo Markov Chain (MCMC) multivariate convergence diagnostics

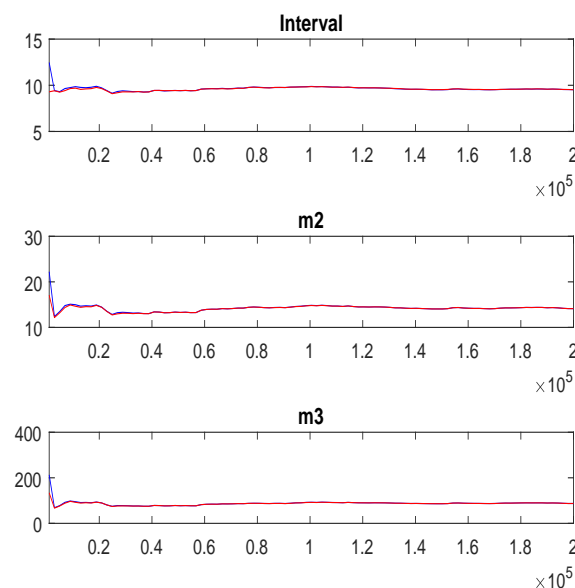


Figure C.4.1: MCMC multivariate convergence diagnostics

## C.5 Model dynamics

Fig. C.5.1 shows the impulse responses of the selected variables to the estimated shocks, at the mean of estimated parameter values. Each row illustrates the impact of a specific shock on variables in columns 1 to 5 (output, policy rate, inflation, house price and total loans).

The first row illustrates the impact of a positive housing demand shock. The shock increases the marginal utility of housing services and drives up households' demand for housing. This leads to an increase in house prices, which in turn stimulates borrowing through the borrowing constraint channel. The increase in borrowing (loans) stimulates aggregate spending in the economy and leads to an increase in output. Despite the increase in aggregate spending and output, inflation declines. This is because the increase in access to external finance (loans), consequent upon the shock, provides an incentive for the entrepreneur to reduce reliance on internal finance (retained earnings) by reducing prices. As a result, inflation declines. This prompts the central bank to reduce the policy rate (nominal interest rate) to counteract the fall in inflation. These results are also consistent with studies such as Gupta and Sun (2018) in the



context of South Africa and Turdaliev and Zhang (2019) in the context of Canada. The second and the third rows (rows 2 and 3) show the impulse responses to a positive shock on the borrowing capacity of the impatient household (row 2) and the entrepreneur (row 3), respectively. In both cases, the shock increases the marginal benefit of housing (as a collateral asset) by improving the valuation of the housing stock. This relaxes the borrowing constraints faced by the impatient household (row 2) and the entrepreneur (row 3) and enables them to borrow more for the given value of the housing stock. Demand for housing increases and drives up house prices. Through the borrowing constraint channel, the increase in house prices leads to an increase in loans and output. As in the case of a positive housing demand shock, inflation declines which in turn prompts the central bank to reduce the policy rate.

Rows 4 and 5 illustrate the impact of a negative household NPL shock and entrepreneur NPL shock, respectively. In both cases, the shock increases the ratio of borrowers' NPLs (household NPLs in row 4 and entrepreneur NPLs in row 5). This in turn increases the bank's loan losses and impairs the bank's net worth (bank capital). Through bank capital requirement constraint, the fall in the bank's net worth forces the bank to adjust its balance sheet by reducing supply of loans in order to continue meeting the regulatory requirement ratio. In addition to this effect, the increase in the borrowers' NPLs drives up lending rates and together with the bank's deleveraging process lead to a decline in total loans, house prices, aggregate spending and output in the economy. Consistent with the empirical findings of Gilchrist et al. (2017), inflation increases despite the fall in aggregate demand and output.<sup>2</sup> As a result, the policy rate increases in order to mitigate the inflationary pressures in the economy. The results compare favourably with Steinbach et al. (2014) and Agénor and Zilberman (2015), in which the authors document that an increase in non-performing loans generates recessionary effects in the economy.

The last three rows illustrate the impact of technology shock, monetary policy shock and cost push shock. The impact of these shock are largely standard and consistent with the literature. A positive productivity shock generates expansionary effects in the economy but leads to a fall in inflation which in turn prompts the central bank to reduce the policy rate. Contractionary monetary policy shock increases the policy rate (nominal interest rate) and leads to a fall in total loans, house prices and inflation. A positive cost-push shock increases inflation. This in turn prompts the central bank to increase the policy rate (nominal interest rate) and generates

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<sup>2</sup>Specifically, Gilchrist et al. (2017) note that due to financial distortions (brought about by the borrowing constraint), firms have incentives to preserve internal financing (profits) by raising prices following adverse financial shocks which increase the cost of accessing external finance (loans).

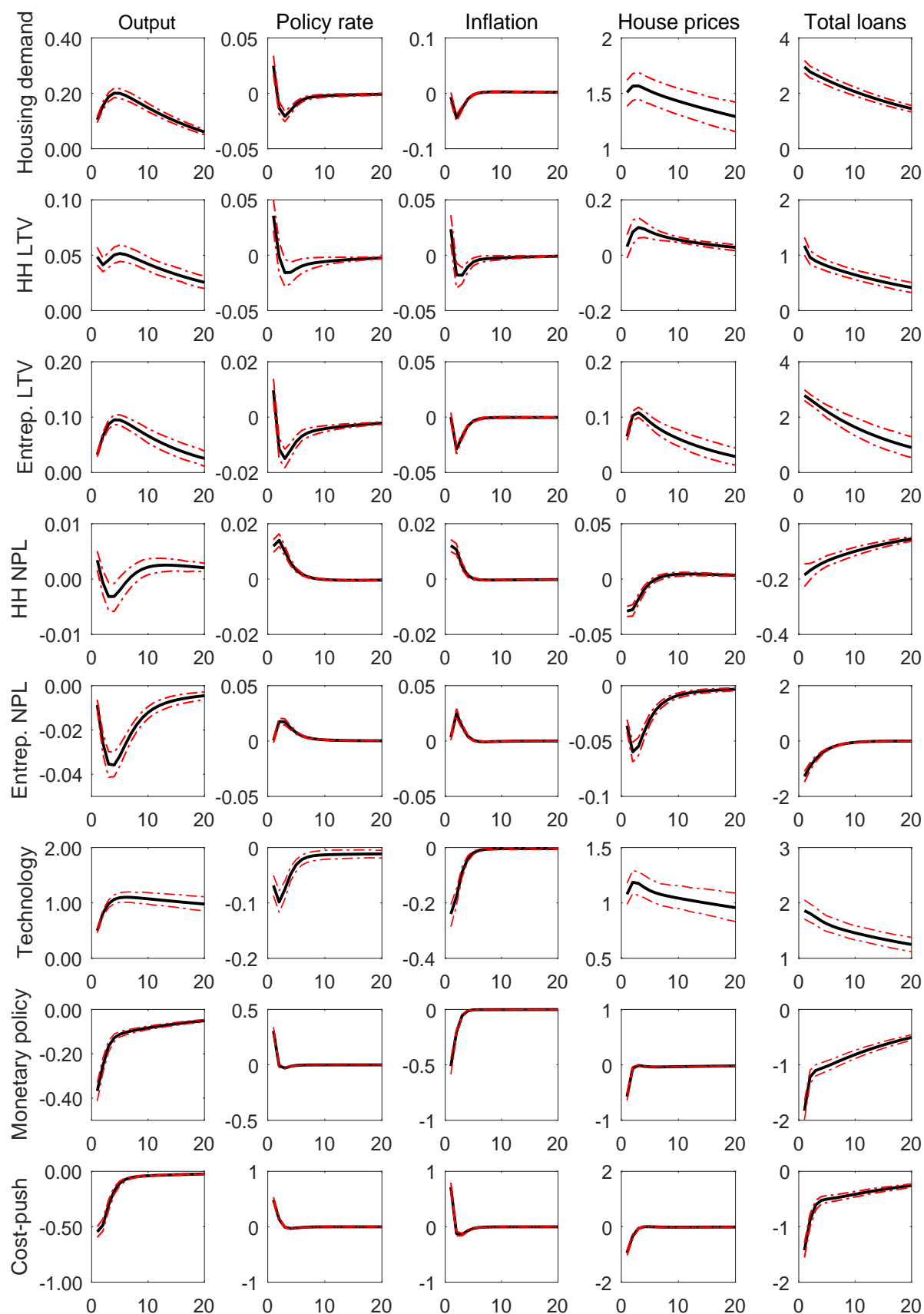


Figure C.5.1: Impulse responses to all shocks considered in this paper. Variables are expressed in % deviations from the steady state while interest rates and inflation are in percentage point deviations from the steady state. HH, Entrep, LTV and NPL stand for household, entrepreneur, loan-to-value and non-performing loans, respectively. The red dotted lines represent the 95% confidence interval, based on posterior distribution. *Ordinate*: time horizon in quarters.

recessionary effects in the economy.

## C.6 Historical decomposition

Fig. C.6.1 shows the historical variance decomposition of output, house prices, household and entrepreneur loans, inflation and nominal interest rate (policy rate) over the estimated sample period 2000Q1–2016Q4. We group household and entrepreneur LTV shocks into LTV shocks and household and entrepreneur NPL shocks into NPL shocks. The historical shock decomposition of output suggests that output dynamics are largely driven by technology shock and monetary policy shock to some extent. The relative contributions of housing demand and credit market shocks are also non-negligible. In particular, housing demand shock contributed positively to output growth from 2002 to 2005 whilst LTV shocks appear to have contributed negatively to growth around the same period. While the fall in output growth during the financial crisis is mainly driven by negative technology shock and somewhat by housing demand and monetary policy shocks, the negative contribution of NPL shocks become evident too. This period coincides with a significant increase in the ratio of household and entrepreneur NPLs. In the housing market, historical shock decomposition of house prices unequivocally shows that housing demand shock is the main driver of house prices. The results suggest that the South African housing market boom period (2000 - 2006), characterised by sustained increase in house prices, was largely driven by housing demand shock. Nevertheless, the subsequent reversal in house prices was driven by a combination of negative technology shocks (particularly during the financial crisis) and negative monetary policy shock in addition to housing demand shock. LTV shocks seem to have a counteracting effect on house price dynamics while the marginal contribution of NPL shocks to a fall in house price during the financial crisis is also evident.

Turning to the credit market, the observation is that most of fluctuations in household loans and entrepreneur loans are driven by credit market shocks (LTV and NPL shocks) and the housing demand shock. The increase in household loans over the period 2002 to 2008 appear to be driven largely by a positive housing demand shock and to a lesser extent by monetary policy and NPL shocks. The subsequent decline in household loans appear to be driven by a combination of a negative housing demand shock, negative NPL, monetary policy and technology shocks, especially from 2008 to 2012. In most cases, LTV shocks appear to be contributing negatively to fluctuations in household loans. On the contrary, most of fluctuations in entrepreneur loans

appear to be driven positively by LTV shocks while housing demand shock appears to have a counteracting effects on the fluctuations in entrepreneur loans. The contribution of NPL shocks to the fluctuations in entrepreneur loans becomes evident during the financial crisis period (2007 – 2009).

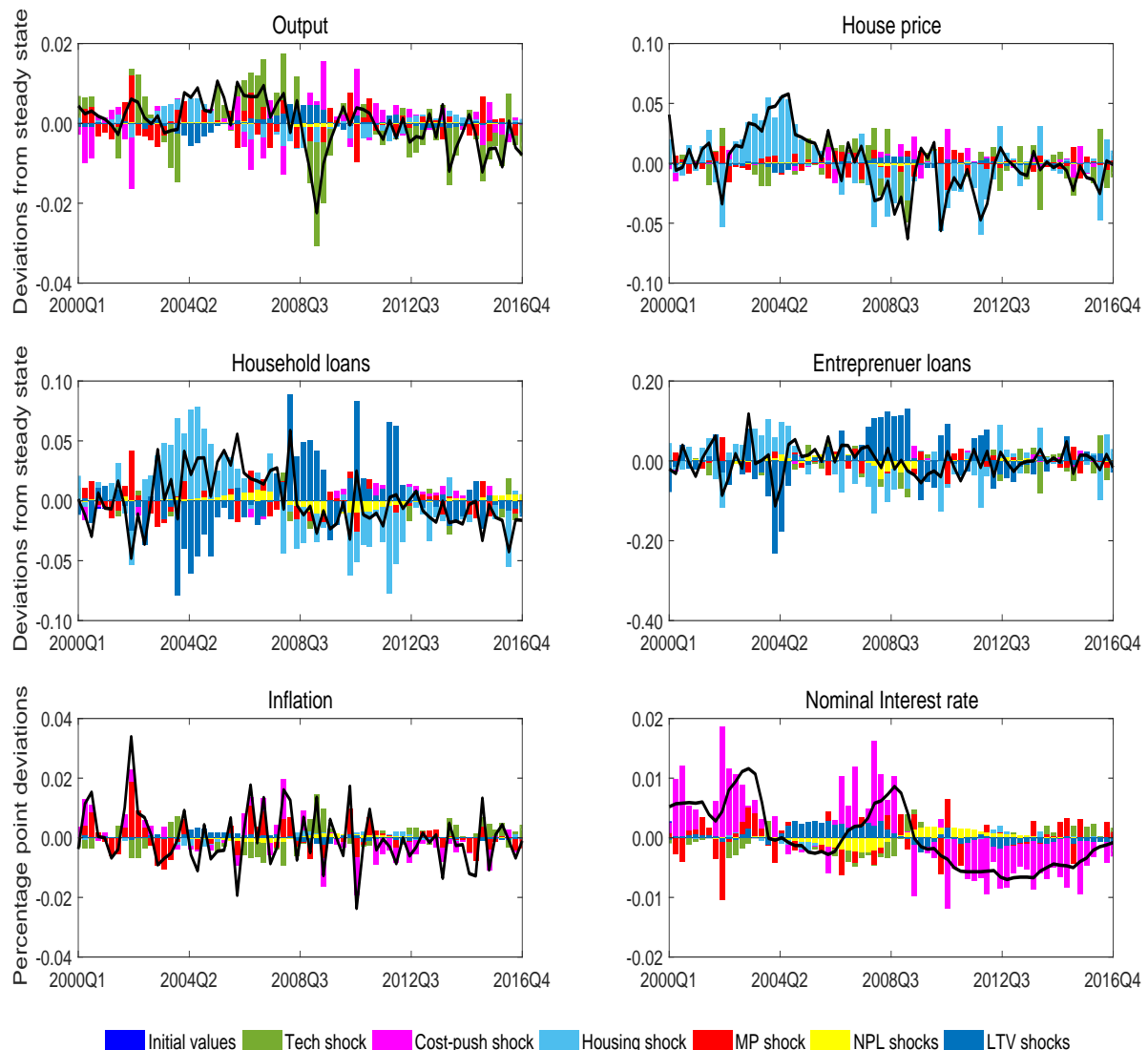


Figure C.6.1: Historical decomposition of output, house prices, household and entrepreneur loans, inflation and nominal interest rate over the period 2000Q1–2016Q4.

Fig. C.6.1 also shows that most of the movements in inflation is mainly driven by monetary policy shock and cost-push shock while movements in interest rate appear to be driven mainly by cost-push shock. This is consistent with the South Africa Reserve Bank monetary policy strategy of inflation targeting. Intuitively, a positive cost-push shock increases inflation. This in turn prompts the central bank to increase nominal interest rate (policy rate). It is also evident

that credit market shocks (LTV and NPL shocks) also played non-negligible role in shaping the movements in nominal interest rate, particularly over the period 2004 to 2013. In summary, Fig. C.6.1 shows that housing demand shock and credit market shocks play significant role in shaping dynamics in the South African economy, particularly dynamics in the housing market and the credit market.

## **C.7 Impulse response functions: entrepreneur LTV and NPL shocks under the three policy regimes.**

### **C.7.1 Entrepreneur LTV shock**

Fig. C.7.1 illustrates the impact of a positive entrepreneur LTV shock. Under the baseline regime, the shock increases the borrowing capacity of the entrepreneur and leads to an increase in demand for housing. This drives up house prices and through the borrowing constraint channel generates expansionary effects in the economy. Demand for loans by both the impatient household and the entrepreneur increases and result in an increase in aggregate spending and output. Inflation declines and prompts the authority to reduce the policy rate. The results show that a simultaneous deployment of monetary and macroprudential policies dampens the expansionary effects of the shock on the economy. Under Policy regime II (a policy combination of a standard monetary policy and macroprudential policy), the authority tightens capital requirement regulation when credit-to-output ratio increases. As a result, the bank reduces the supply of loans to the two credit-dependent agents. Both the impatient household and the entrepreneur reduce investment in housing. This in turn dampens the increase in house prices and the extent of the increase in consumption and output in comparison to the benchmark regime.

The results further show that allowing the monetary policy to react to emerging financial imbalances (Policy III) generates substantial gains in terms of financial stability in comparison to Policy II. In this case, the authority increases the policy rate in response to the increase in credit growth. The increase in the policy rate prompts the patient household to reduce consumption and this exerts dampening effect on consumption. Through the expectation channel, the impatient household and the entrepreneur reduce demand for loans in anticipation of high interest rates consequent upon the monetary policy reaction to credit growth. The impatient household's lending rate declines on impact because of a substantial reduction in the impatient household's

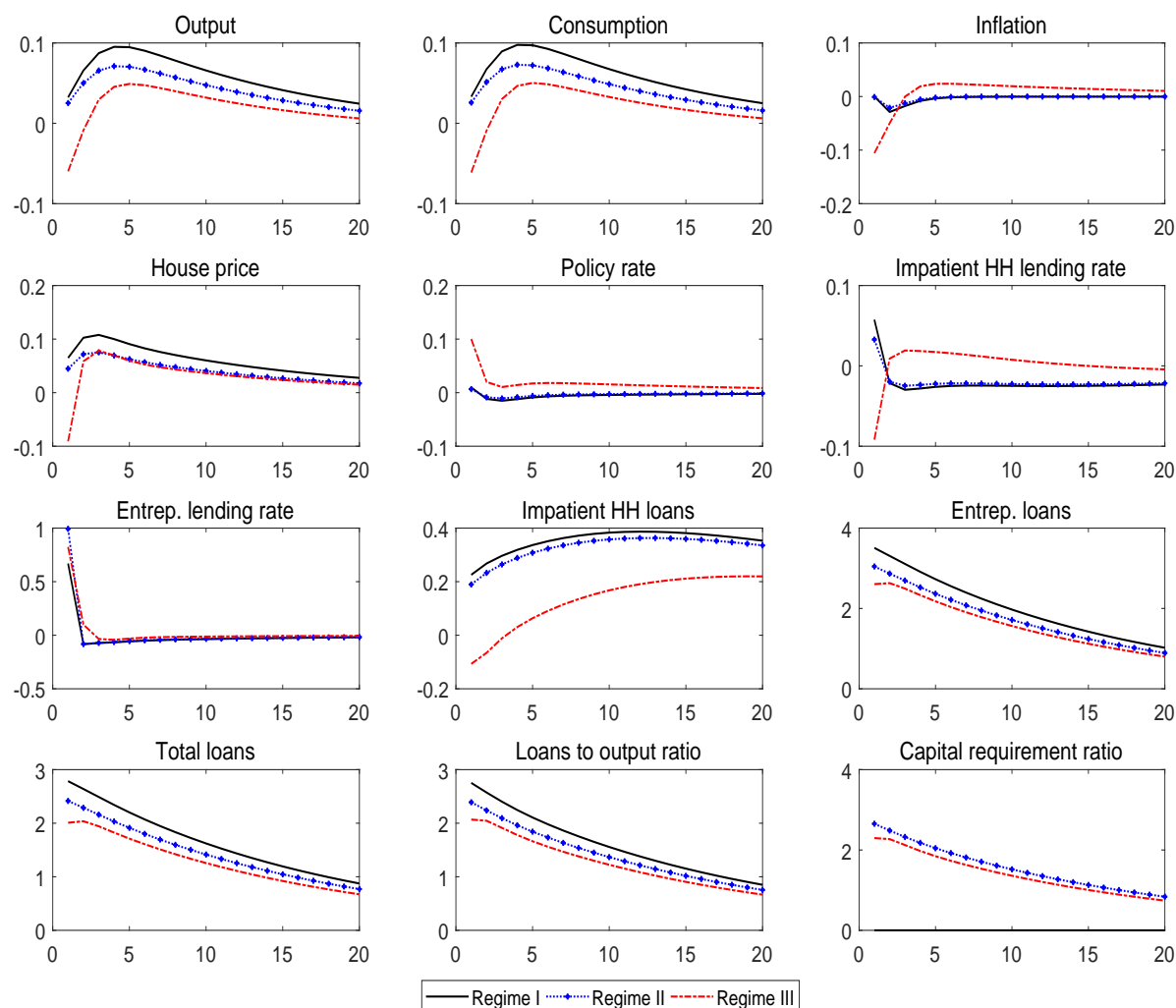


Figure C.7.1: Impulse responses to a positive entrepreneur LTV shock under the three policy regimes: Policy I, Policy II and Policy III. Variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage points. HH and Entrep stand for household and entrepreneur, respectively. *Ordinate*: time horizon in quarters.

loans. As a result of the fall in total loans, credit-dependent agents reduces their consumption and together with the reduction in the patient household consumption leads to a decline in aggregate consumption and hence output in comparison to Policy II. We also find that Policy III generates a trade-off between financial stability and price stability. Policy III induces an over-reaction in the real sector and increases volatilities of the policy rate and inflation. On the contrary, the policy regime that combines a standard monetary policy and macroprudential policy (Policy II) mitigates these costs. In particular, such a policy combination enhances the overall stability within the economy.

## C.7.2 Entrepreneur NPL shock

Fig. C.7.2 displays the dynamic effects of a negative shock to entrepreneur NPLs. Under the benchmark regime (Policy I), the shock increases entrepreneur NPLs and result in an increase in the bank's loan losses. This reduces the bank's net worth and forces the bank to adjust its balance sheet by reducing supply of loans, particularly to the entrepreneur (a more risky borrower). The entrepreneur lending rate also increases due to the increase in perceived entrepreneur's credit risk and further exert downward pressure on the entrepreneur's demand for loans. Meanwhile, impatient household lending rate declines and induces the household to increase demand for loans. The fall in entrepreneur loans prompts the entrepreneur to reduce investment in housing and productivity within the economy. This in turn drags down house prices and, through borrowing constraint, leads to a fall in total loans, consumption and output. Inflation, on the other hand, increases and prompts the central bank to increase the policy rate.

When the authority complements monetary policy with macroprudential policy, the negative impact of the shock is dampened. In this case, the regulator relaxes capital requirement regulation as credit-to-output ratio declines. This reduces pressure on the bank to adjust its balance sheet aggressively in comparison to the benchmark regime. As a result, the extent of a decline in total loans becomes smaller under the regime that combines monetary policy and CcCR regulation, particularly under Policy III, than under the benchmark regime. This mitigates the spill-over effects of the shock to the housing market and the real sector and results in a reduced fall in house prices, consumption and output. Again, the reduction is more pronounced under Policy III than under Policy II. In the credit (loan) market, we observe that the policy regime that combines monetary policy and CcCR regulation, particularly Policy III, mitigates the decline in entrepreneur loans and reduces the extent of an increase in entrepreneur lending rate. At the same time, this policy combination attenuates the increase in household loans. However, in this case the attenuation effect is larger under Policy II than under Policy III.

In a nutshell, the results suggest that the stabilisation effects of Policy III marginal outperforms that of Policy II, especially at aggregate level. However, as is the case with LTV shock, allowing the monetary policy to react to emerging financial imbalances compromises price stability. In this case, the policy rate declines sharply in response to a fall in credit. This prompts the patient household to increase consumption on impact, through an intertemporal substitution effects. At the same time, the forward-looking borrowers (the impatient household and the entrepreneur) takes into account the potential drop in the interest rates and react by increasing

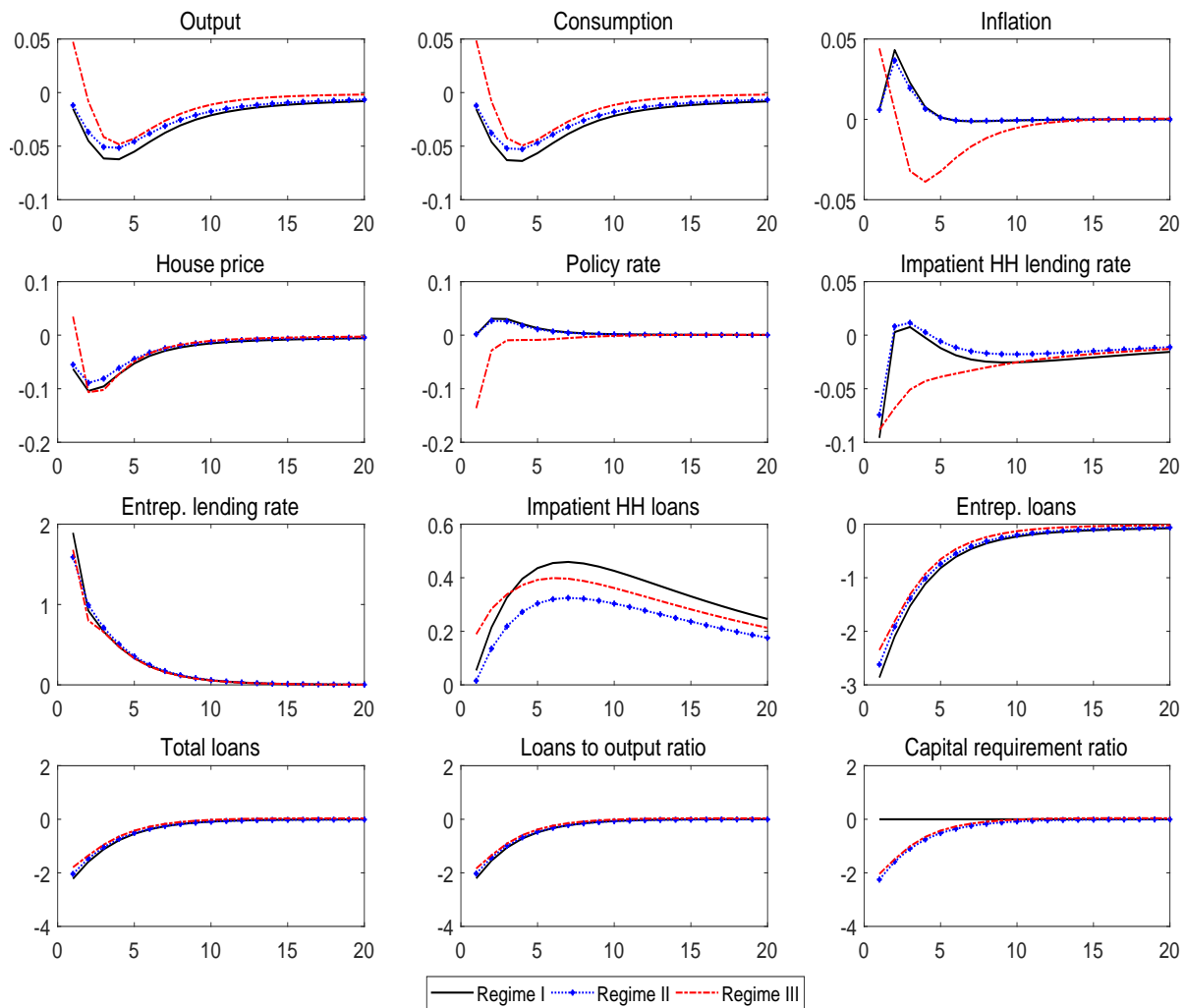


Figure C.7.2: Impulse responses to a negative shock to entrepreneur non-performing loans under the three policy regimes: Policy I, Policy II and Policy III. Variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage points. HH and Entrep stand for household and entrepreneur, respectively. *Ordinate*: time horizon in quarters.

demand for loans. As a result, consumption of the impatient household and the entrepreneur falls by less under Policy III than under Policy II, and together with the increase in consumption of the patient household leads to a reduced fall in aggregate consumption and output. Meanwhile inflation drops following an increase on impact. Similar to the case of LTV shock, the results suggest that allowing monetary policy to react to credit growth induces an over-reaction in the real sector and increases volatilities of the policy rate and inflation.



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